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Finer Points

SUPERABRASIVE INDUSTRY REVIEW

Featuring Lasers At Work In The Superabrasive Industry

THIS ISSUE

Industrial Diamond Association of America Biennial Meeting Overview

Wetter Is Better – New Developments In Wet Laser Machining For Industrial Diamond Tools

IDA Member Companies

Superabrasive Materials, Principles and Applications – Course Review

Guest Editorial

Nanosecond Laser Processing of Diamond Materials

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6 Axis Green Laser Sawing & Shaping for Hard Materials

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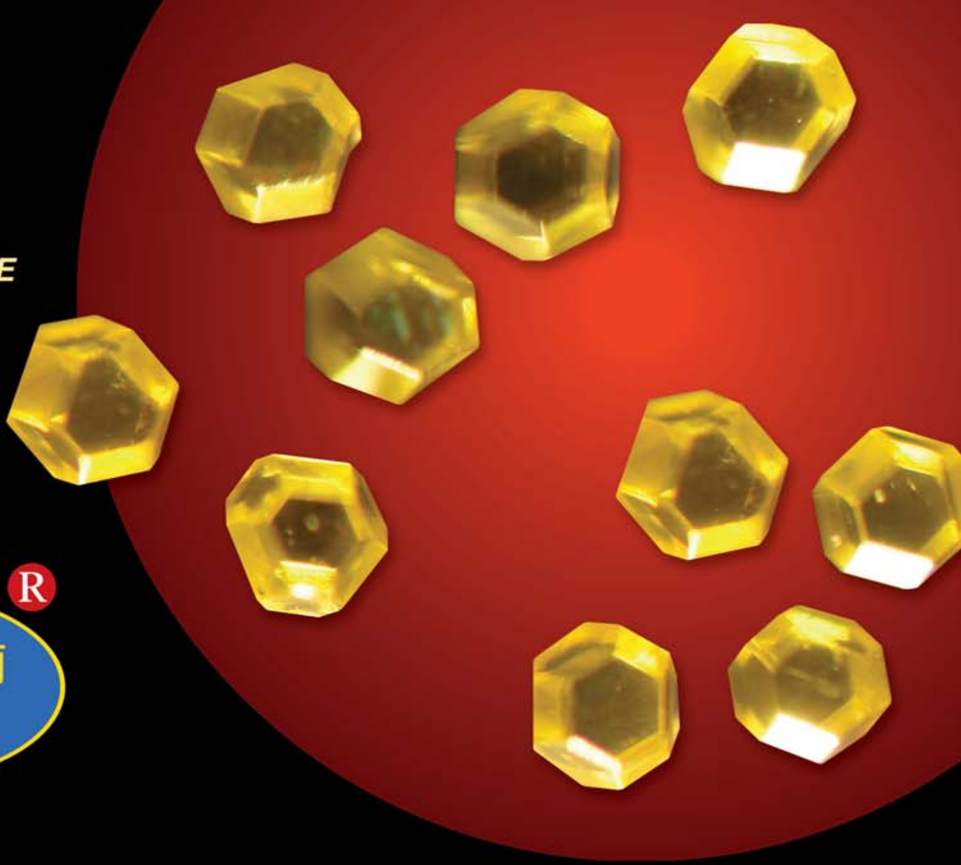

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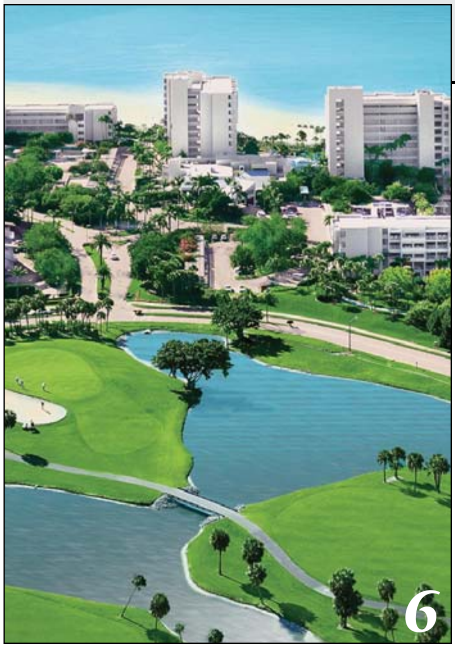

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COVER PHOTO

SYNOVA Laser-Microjet® cutting of Polycrystalline Diamond (PCD) Tool. Super hard materials are commonly used as cutting tools due to their hardness and thermal conductivity. This category consists of materials like CBN (cubic boron nitride), PCD (polycrystalline diamond), PCBN (polycrystalline cubic boron nitride), or silicon nitride. The inserts have to be cut out of a disc or plate. Typical geometries are triangular, rectangular or lozenge-shaped. The main requirements are: smooth edged surfaces, a parallel cutting kerf, and a narrow kerf in order to lose the least material possible. It is also necessary to avoid burrs and material changes due to heating, and to reach reasonable speed and flexibility in order to realize any shape.

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FINER POINTS is the longest running publication devoted exclusively to the understanding, selection and application of diamond, cubic boron nitride and related materials. It is edited for recipients who are involved in some way with these “superabrasives”, either as providers of the materials, producers of products containing the materials or users of these products (e.g., grinding wheels, dressing tools, drill bits, saw blades, sawing wires, cutting tools, polishing compounds, CVD film products, etc.).

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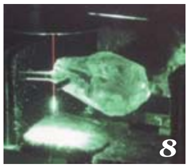
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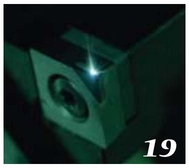
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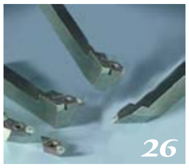
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A Finer Point of View…

The IDA has always believed that in order to expand the market for diamond tools that it was essential to provide the users and manufacturers of diamond and Cubic Boron Nitride tools with the latest technical developments in order to efficiently machine, grind and shape materials.

In addition to presenting INTERTECH every two years the IDA decided to produce a series of education seminars.

This past November Industrial Diamond Association of America (IDA) Member YG1 USA hosted an IDA two day education course at their new technical and manufacturing center in Charlotte, North Carolina. Thank you Shane Hollenbaugh and Jason Wells! These excellent facilities enabled the IDA to complement classroom presentations with machining and grinding demonstrations.

We had 71 attendees from 15 different states. In addition, Erol Keskin traveled from Istanbul Turkey, Paul Schildkraut from Antwerp, Belgium and Dr Abdelatif Atarsia from Montreal Canada.

The program was divided into two parts, day one Grinding and day two Machining with Diamond and CBN tools.

We owe a great deal of thanks to our Education Committee chaired by David Spelbrink and Scott Ries for all their hard work in organizing the entire program, lecturers and demonstrations.

Thank you to Dr. Jeffery Badger, Dr. Abdelatif Atarsia, Ed Francis, Don Gieseke, Shayne Miller, William Shaffer, Aaron Nolan and David Spelbrink for their excellent presentations. We must also thank the YG1 machine operators for their assistance in running the demonstrations.

PRESIDENT
Keith Reckling

I would especially like to thank Attila Szucs and Brian Jones of Advanced Superabrasives Inc. for bringing their diamond wheel truing and dressing unit to the seminar and for an excellent demonstration of the unit. Proper truing and dressing of diamond wheels is most important and has a big effect on the diamond or CBN wheels performance.

I would like to acknowledge all the hard work and time Kathy and Terry Kane spent organizing and managing the seminar, thank you Kathy and Terry.

The IDA will be organizing one or two and education Seminars in 2016 and if any member would like to host a seminar or participate as an instructor please contact Terry Kane or our education committee.

As I finish my term as President, and undertake my new role as Past President, I will continue to pursue the IDA goal of "Growth through Education" in 2016.

Sincerely,

Keith Reckling

Keith Reckling, IDA President 2015
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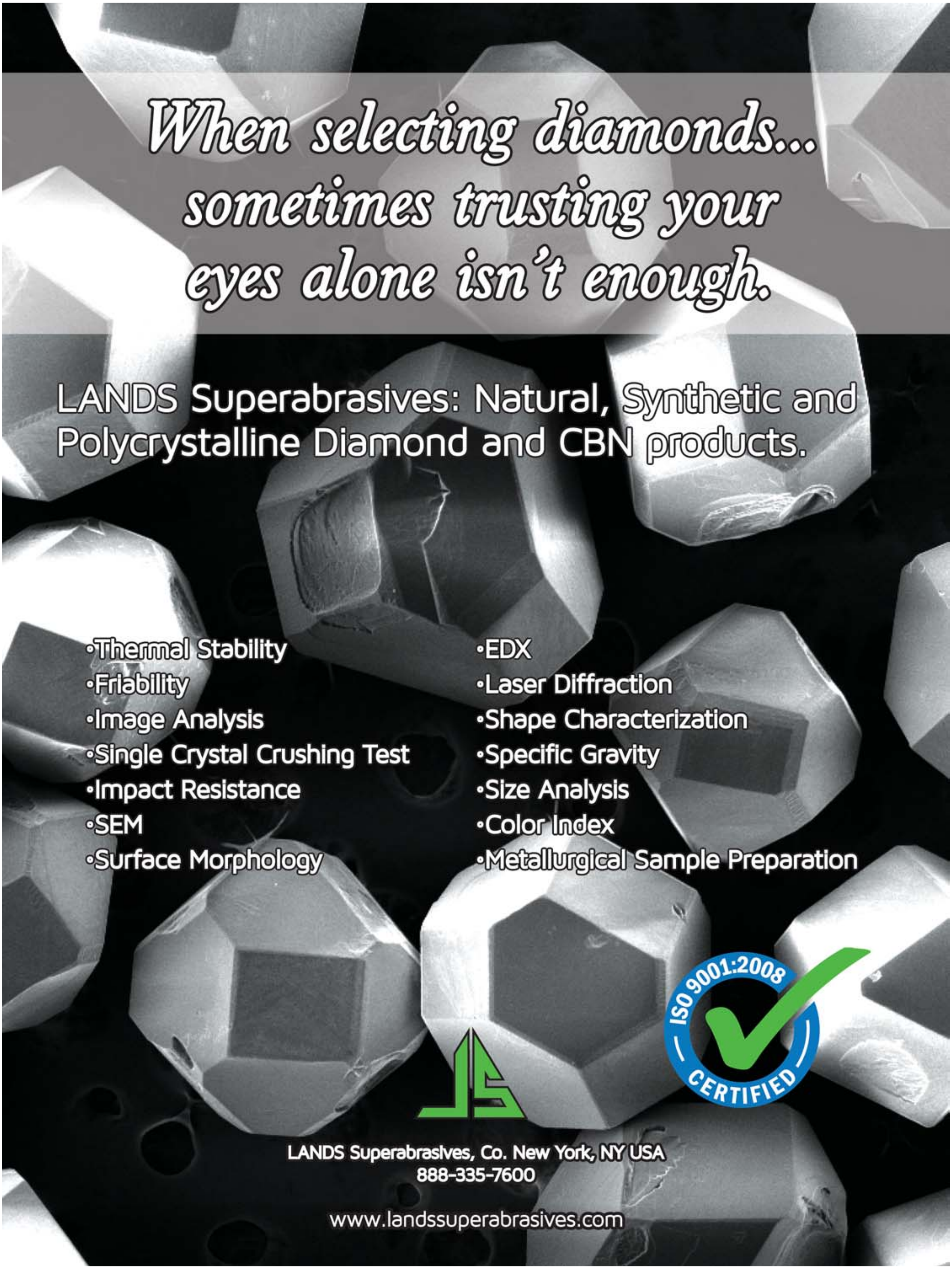

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INDUSTRIAL DIAMOND ASSOCIATION OF AMERICA (IDA)

Biennial Meeting OVERVIEW

April 11-13, 2016

Longboat Key Club Resort

LONGBOAT KEY, FLORIDA

The Industrial Diamond Association of America is Celebrating 70 Years!

In an effort to make the IDA Annual Meetings more user friendly in INTERTECH years, the IDA Board of Directors with the approval of the General Membership have opted to change from a yearly Annual Meeting to a Biennial Meeting on alternating years with INTERTECH. The first meeting has been planned as a joint meeting with the Unified Abrasives Manufacturers Association (UAMA) and therefore we will share certain meeting and speaker events that are applicable to both Associations. During this meeting the IDA will also hold separate, focused business meetings and planning sessions for IDA events. ***Your attendance is an investment in the future success of your business and in our industry as a whole!***

With the tremendous success of ***INTERTECH Conferences*** and our education course, ***Superabrasive Materials, Principles and Applications***, the Board feels it is critical that all Members make an effort to participate since we are now only holding these meetings every other year.

The IDA has reached and surpassed our goals over the past few years and it is important that we continue this momentum with the active participation of our membership. Remember, this is the only time when we can all meet as suppliers, customers, competitors and colleagues to share in marketing goals and address issues that affect us all throughout all the industries we serve. Here is your chance to have a say in your Associations activities and share in that feeling of accomplishment for a successful Association! This Meeting will be held April 11-13, 2016 at the Resort at Longboat Key Club in Sarasota, Florida. Secluded on a barrier island in the Gulf of Mexico, the environmentally-friendly resort is an official Florida "Green Lodging" and just a short drive from the shopping, museums and theaters in downtown Sarasota.

Along with breathtaking ocean views, guests enjoy oversized accommodations with private balconies, eight diverse restaurants & lounges, premier golf and a full-service beachfront offering of water sports and relaxation. This Sarasota resort will set the stage for a successful and memorable Biennial Meeting of the IDA and UAMA! Make your hotel Reservations and Register for this exceptional and historical Biennial Meeting now at **www.superabrasives.org** and view all the details and meeting opportunities offered at this important Industry and Association event.

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Wetter Is Better – New Developments In Wet Laser Machining For Industrial Diamond Tools

By: Dr. Peter J Heath and Mr Sébastien Kurzen
SYNOVA S.A., Switzerland

INTRODUCTION

With a traditional dry laser, the machining is either carried out completely dry or under a gas atmosphere. Under such dry conditions, heat can build in the work piece, thermal expansion can result in distortions, brittle materials may crack and a large heat affected zone (HAZ) and oxidation may also result. A gas may give a better atmosphere but it does not have sufficient thermal capacity for adequate cooling. Last but not least, the cut produced by a dry, focused laser beam is "V" shaped – the kerf is wider at the entry side of the cut than at the laser's focal point at bottom of the cut.

A wet laser is very different. It works by first focusing the laser onto the aperture of a water jet nozzle. The water jet is typically 50 microns in diameter and up to 50mm in length before it turns to droplets. The laser pulses travel down this liquid optical 'fibre' by total internal reflection. The laser-water-jet cuts the workpiece by repeatedly scanning the required cutting pattern so deepening the trench. As a result, the cut produced is parallel sided rather than 'V' shaped and it is constantly cooled and cleaned of debris by the 300 bar water jet (Figure 1).

There are many application areas for the wet laser from drilling holes in ceramic coated, superalloy turbine blades to cutting gears for luxury watches. Various lasers can be employed but for the diamond industry, a Nd:YAG laser at a wavelength of 532nm and a pulse frequency of the order of a few kHz has been found to be the most appropriate.

Water is particularly transparent to light of this wavelength. The scanning speed used is typically of the order of 10-20mm/sec and the amount of material removed at each pass is of the order of 20-50µm. In the following case studies, the various advantages of wet laser machining will become clear.

CASE STUDY 1: Gem Diamond Sawing and Daceting

Over the last 2 years, there has been significant uptake of the wet laser in the gem diamond industry. Over 30 wet lasers are now running for 'sawing' gem diamond in India, Belgium, Thailand, Russia and South Africa. Figure 2(a) shows a 200ct gem stone being cut into the required primary parts. More recently, the wet laser manufacturer has started to develop the techniques to expand applications and cut the major facets Figure 2(b) on stones so as minimize the amount of polishing required.

In comparison to dry lasers, the benefits of wet lasers for the gem diamond industry can be summarised as:

1. Increased yield (stone weight) via reduced breakage rate of stressed stones
2. Increased yield due to the narrower, parallel sided kerf
3. Faster cutting rates and higher productivity at higher laser powers without thermal damage
4. A simpler planning process as the kerf is not V shaped
5. Easier cutting as double sawing is not necessary – cuts 25mm deep achieved from one side
6. Flatter, more accurate facets ready for final polishing
7. Minimal sub-surface damage

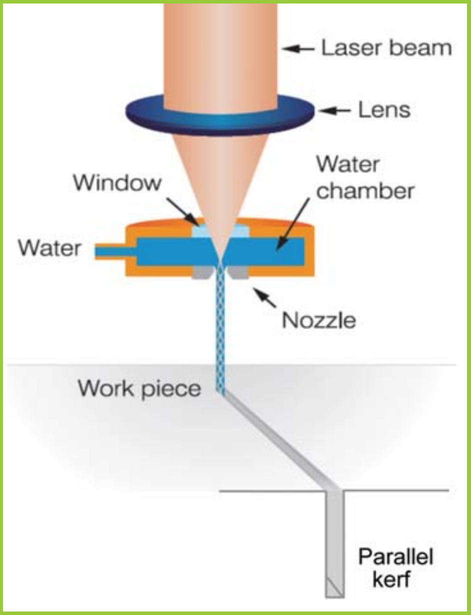

Figure 1 **– Schematic of the Water Jet Laser**

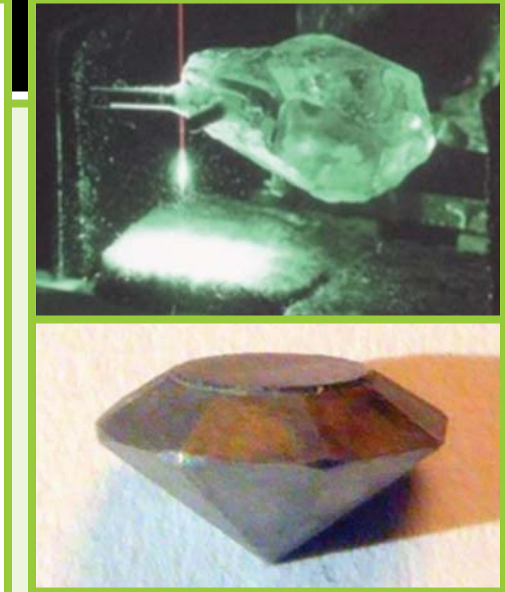

Figure 2 **– 2(a) A 200ct Gem Stone Being Wet Laser Cut. Figure 2(b) Primary Facets Wet Laser Cut**

CASE STUDY 2: Drilling and Trepanning Rods from Gem Diamond

A most interesting capability of the wet laser is to make parallel sided holes in difficult materials or alternatively, the wet laser can be used to produce rods of any shape such as triangular, square or round cylinders. In Figure 3, a diamond rod 1mm diameter and 8 mm long has been cut from a natural diamond stone in less than 8 minutes. The end to end diameter of the rod produced was within ±2 microns.

CASE STUDY 3: Cutting Synthetic, HPHT Diamond

One of the most common methods for single crystal diamond tool manufacture, be they natural or synthetic diamond, is to first braze the diamond to a tool body using a reactive/active braze alloy and to then, by grinding, ‘block out’ an approximation to the radius required as a series of facets. This ‘blocking out’ can be quite a tedious and time consuming process for operators.

Cutting synthetic HPHT diamond (Figure 4) with the wet laser enables a near net size shape to be achieved in just a few minutes. In addition, the excess waste diamond is not ground away to dust but is removed as a piece from which other tools can be made. Dry lasers have been used to cut profiles and forms in diamond but tool makers have reported that dry lasers introduce thermal micro-cracks into the cut diamond surface and blocking out is still required to remove these defects. The water of the wet laser gives very efficient ‘in-process cooling’ and excessive thermal stresses are avoided. Using a wet laser, only a minimal amount of final lapping is required to complete a precision tool using a scaife bench, a planetary radius grinding machine[1] or a form grinding machine. Tests are underway to confirm that wet laser cut diamond edges for use in machining very abrasive work pieces (for example, laminate flooring or carbon fibre composites), can be used ‘as-cut’ without further processing.

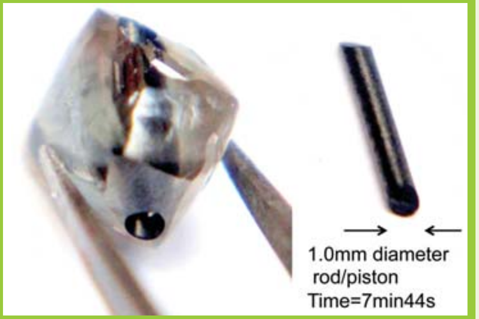

Figure 3 **– A 1.0mm Rod Cored from a Natural Diamond**

CASE STUDY 4: Cutting and Slicing Polycrystalline CVD Diamond Tools

Like natural and HPHT diamond, CVD diamond is also easily shaped with the wet laser. Sharp chip free edges can be achieved as shown in Figure 5. In polycrystalline CVD diamond, it has been noted that the ablation rate varies slightly with crystal orientation and the columnar crystal structure of polycrystalline CVD diamond can sometimes be seen in the clean, water scoured cut surfaces. As indicated earlier, ultra-precision, low waviness tools, will still require final fine lapping operations but tools for coarse work pieces could be used ‘as cut’.

Another CVD diamond requirement is the cutting of thick plates into thin slices. A specific situation is to remove the rough, polycrystalline growth surface so as to produce a smoother, flat face ready for final mirror polishing.

Figure 6 shows a 6mm x 5mm x 0.5mm wafer of CVD diamond which has been sliced in half. The kerf is 50µm, leaving slices 0.225mm thick.

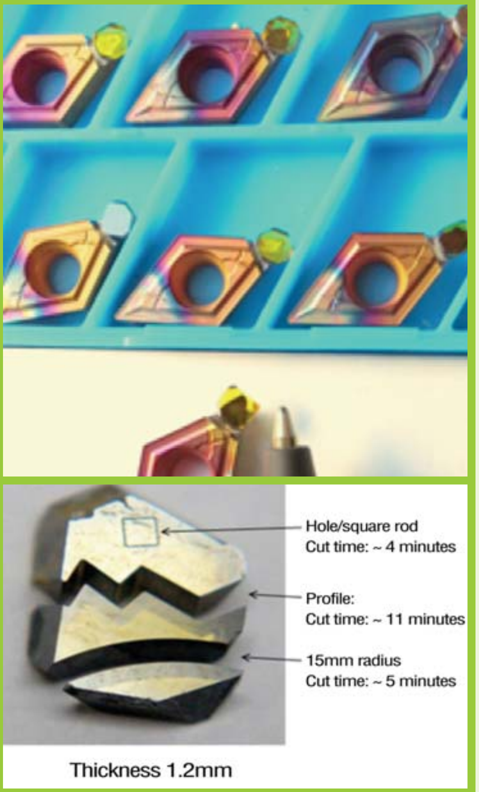

Figure 4 **– HPHT Diamond Cuts**

CASE STUDY 5: Making PCD Glass Scribing Wheel Blanks

PCD glass scribing wheels are typically 2.8mm diameter with a 0.8mm bore. A common starting point when making these small wheels, is to first grind away the carbide substrate of a standard PCD mother disc so as to create a solid PCD wafer from which the blanks are then cut. An alternative approach is to retain the carbide substrate and simply trepan into the PCD layer using a the wet laser and to then release the 2.8mm discs by cutting within the PCD layer, parallel to the

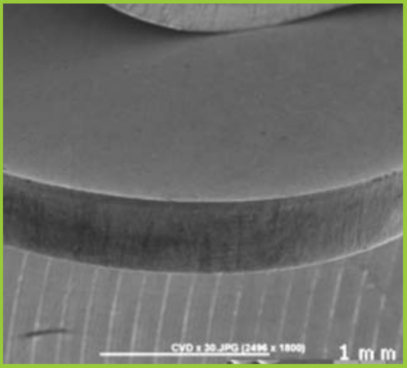

Figure 5 **– A Radius Cut on a CVD Diamond Blank. Note the Chip Free Edge.**

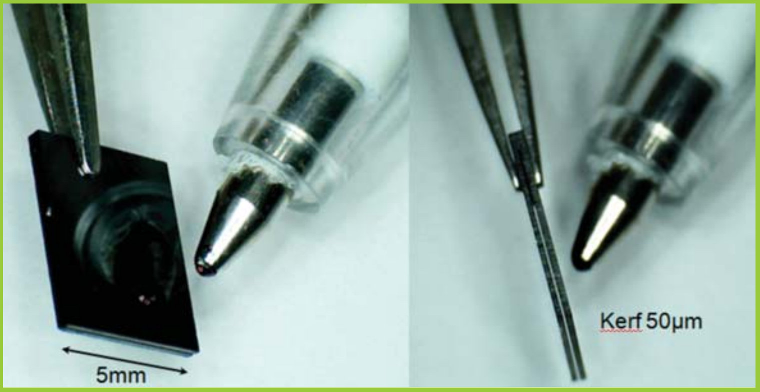

Figure 6 **– Slicing CVD Diamond**

Figure 7 **– A PCD Glass Scribing Wheel**

top surface. (Figure 8). A further advantage for the wet laser is that it does not need to be re-focussed if it is cutting a non-flat surface. A higher disc packing density can be achieved in this example by laying out the circles along strips of PCD made up of close packed hexagons cut from the mother disc. Even though the cut to release the discs is into a convoluted surface, the wet laser can cut and release the PCD discs without worrying about re-focussing (Figure 9).

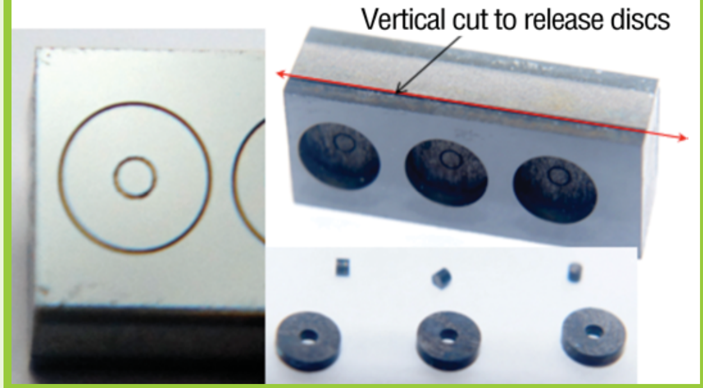

Figure 8 **– Showing How Discs of PCD Can Be Released Rrom The Carbide Substrate**

CASE STUDY 6: Comparing EDM Wire Cutting and Wet Laser Cutting

Diamond is a non-conductor of electricity. EDM wire cutting of PCD relies on the electrical conductivity provided by the trace of remnant cobalt metal left in the PCD layer after the HPHT pressing cycle. With wire cutting, the carbide and PCD layers are cut simultaneously from the side by a wire typically 250 µm in diameter. The kerf width produced is approximately 300 µm. In contrast, the wet laser scans the surface and cuts vertically downwards by forming a deeper and deeper trench (Figure 10).

Firstly it is clear that access to only one side of the workpiece (tool) is required and secondly, this totally different cutting regime gives opportunity to change power levels under program control as the material is cut: low power can be used on entry whilst trenching the PCD layer so as to maximize cut perfection and the power level can be increased when cutting the carbide to maximize cutting speed.

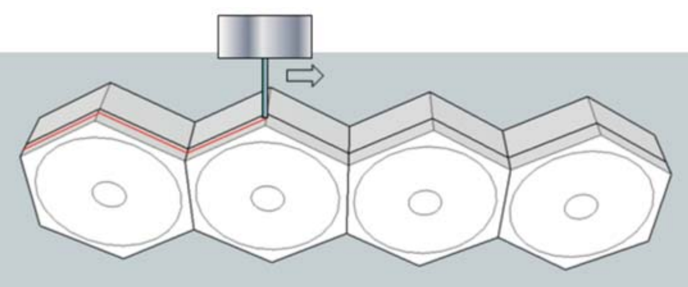

Figure 9 **– Illustrating That There is No Need to Re-focus a Wet Laser**

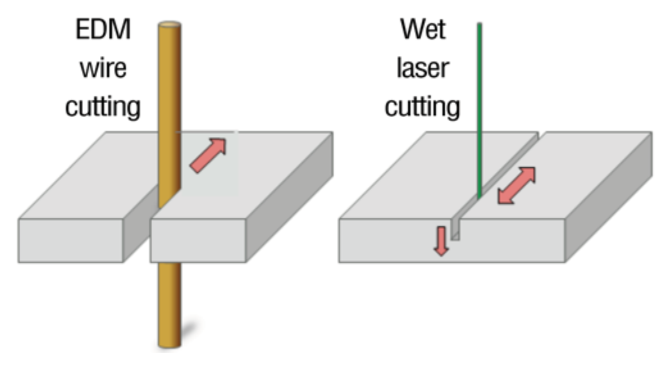

Figure 10 **– Comparison of wire cutting and wet laser cutting regimes**

CASE STUDY 7: Dry Laser Cutting v. Wet Laser Cutting of Cemented Carbide

Cemented carbide is quite difficult to cut with dry lasers. Dry lasers melt the cobalt of the carbide and, even with high pressure gas assistance, the debris is not ejected from the cutting zone. The cobalt re-solidifies within the kerf and the resultant cut surfaces are unsightly in appearance (Figure 11). In many situations, the dry laser cut surfaces re-join as the molten cobalt re-solidifies.

In contrast, the intense water flow of the laser water-jet 'water-atomises' and rapidly solidifies the molten cobalt into discrete powder particles which are then efficiently ejected leaving the kerf with clean smooth walls. In addition, the water mops up any cobalt fumes: health and safety requirements for dry lasers require sophisticated fume extraction to trap cobalt when carbide is being cut. As an example, Figure 12 show PCD drill slugs of 10mm diameter and with a heights of 5.2mm and 9.2mm respectively which have been cut from the ex-press compacts. The cutting times were 4.3 mins and 8.0 mins, which equate to effective cutting speeds (Speed(eff))of 7.3 and 3.9mm/min, respectively. Use of a higher power, double cavity laser would reduce these cutting times further. The cut surface produced is uniform, taper free and the carbide substrate has a clean, matte, metallic silver colouring ready for brazing.

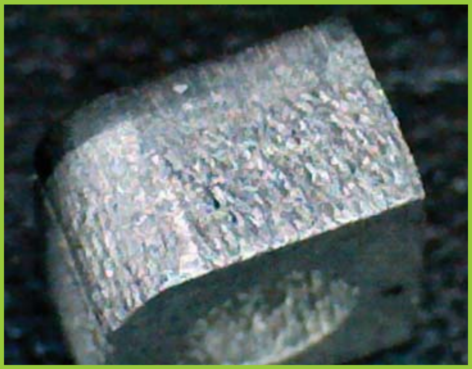

Figure 11 – The Rough Surface Produced When Dry Laser Cutting Cemented Carbide

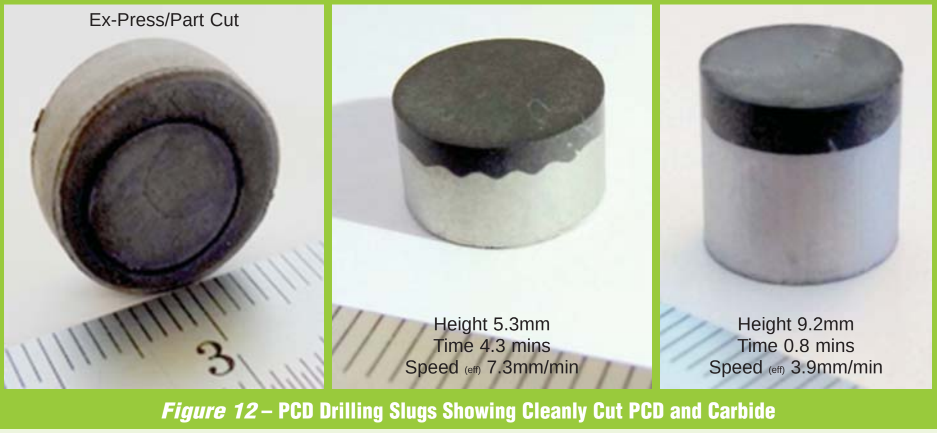

Figure 12 – PCD Drilling Slugs Showing Cleanly Cut PCD and Carbide

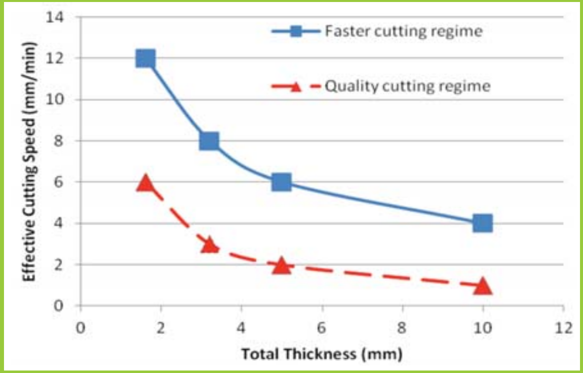

Figure 13 – Showing the Relationship Between Thickness & Effective Cutting Speed Using a 50um Laser Water Jet on Cemented Carbide

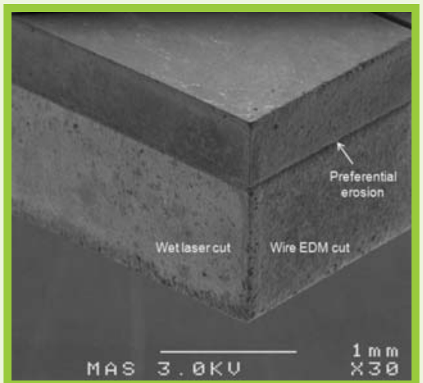

Figure 14 – Showing Flank Appearance For Wet Laser (left) and Wire Cutting (right)

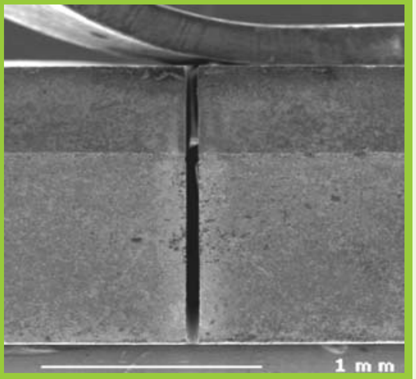

Figure 15 – Showing a Cross-Section Through a Parallel Sided, 50µm Wide Kerf in 1.6mm PCD

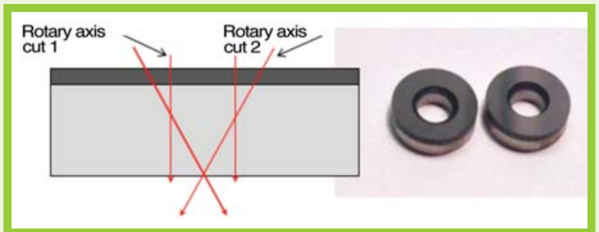

Figure 16 – Cutting Holes and Internal Chamfers Into Full-Face PcBN Inserts

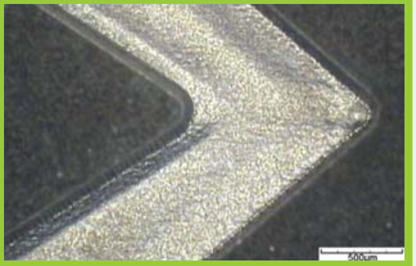

Figure 15 – Chipbreaker Cut Into Surface of PCD Tool

Finally, it should also be noted that, because the slugs have been cut by trepanning, there is no 'pippi' produced as happens with wire cutting when the wire breaks through into a previously cut kerf.

CASE STUDY 8: The Wet Laser and PCD Cutting Tools

(a) Wet laser cutting speed v. wire cutting speeds

Wire EDM machines often use a cutting strategy in which the tool flank is cut in stages with each pass being done at reducing power levels so as to minimize the damage produced in the PCD but as the power reduces so does cutting speed. Excellent edge quality can be achieved but the total production time for a tool can become quite long. A busy toolmaker may then need to buy many wire machines for his required production volume.

The forced water cooling of the 300 bar water jet allows more laser power to be used without increasing thermal damage. As with wire cutting, the effective cutting speed of a wet laser decreases with increasing workpiece thickness and to enhance cutting rates larger nozzles can be employed if required. Typical effective cutting speeds on various thicknesses of carbide backed PCD are shown in Figure 13 under 'faster' and 'higher quality' cutting regimes. At very high power levels, cut quality starts to decrease and side effects such as scan striations may start to show in the kerf walls.

(b) The 'undercut' problem of wire cutting

Carbide backed PCD often shows a high concentration of cobalt at the interface between the carbide substrate and the PCD above. As a result, this layer has a higher electrical conductivity than the material either side of the interface which encourages preferential erosion to occur thus forming a groove or 'undercut' (Figure 14). The toolmaker must leave an excessive amount of oversize on the PCD so as to be sure the undercut is removed during subsequent (lower power), wire cutting passes or grinding operations.

Since the wet laser machining process is independent of electrical conductivity, undercuts do not form and perfectly flat surfaces are produced with no step or groove at the carbide/diamond interface as seen on the left, wet laser cut flank of Figure 15.

CASE STUDY 9: Creating 'Pin-Lock' Holes in Full Face PCD/PcBN Inserts

Toolmakers have long wanted an easy way to make holes in solid and carbide backed PCD/PcBN blanks so that they can produce 'full-face' inserts for 'pinlock' toolholders or hold the blank on the end of a stub for OD grinding. EDM die sinking can be used but this is a slow process as a significant amount of material has to be removed. Wire EDM could be used but first the blank has to be pierced and the wire threaded through the hole. If the material is a solid, low electrical conductivity product, e.g. a high cBN content PcBN or 'binderless' PCD, EDM methods will not work. However, the wet laser can cut the required hole and internal chamfer in a simple two stage operation, whatever the material, as shown Figure 16.

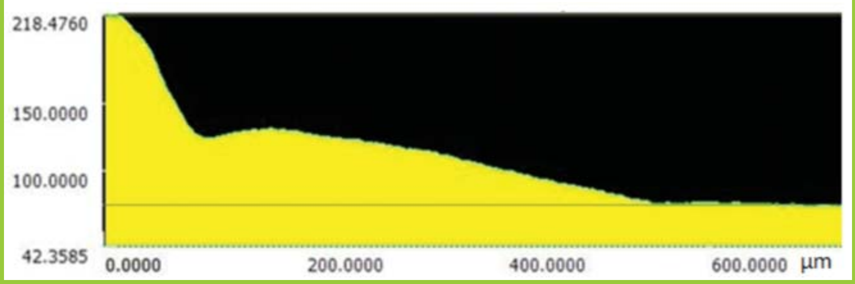

Figure 18 **– Showing Profile of Chipbreaker Cut in 8 Minutes**

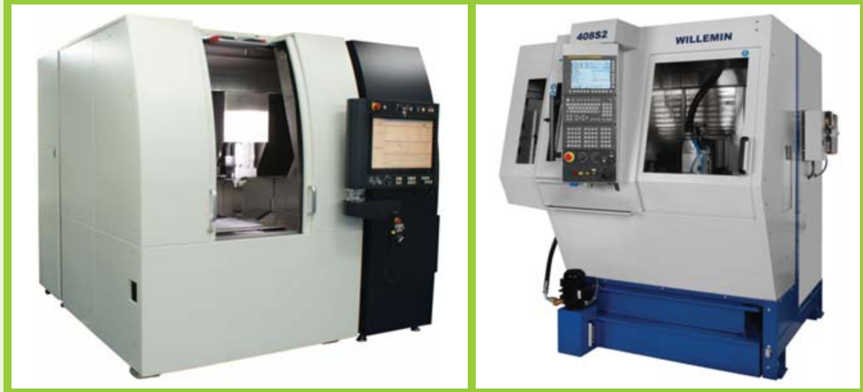

Figure 19 **– 5 Axis Wet Lasers Using Makino & Willemin-Macodel Platforms**

CASE STUDY 10: Making Chipbreakers

With suitable programming it is of course possible to create chip-breakers with a wet laser as shown in Figure 17. In this example, the arms of this profile cut into the surface of polished PCD were some 4.8 mm long and the total area was 25mm2. The maximum depth of the profile was 160µm. By varying where the wet laser scanned, the shape and depth of the floor of the chipbreaker was controlled as shown in Figure 18.

Tool Making with Wet Lasers Having 5 Simultaneous Axes

All the above examples were carried out on 3 axis machines with some applications using a separate 4th rotary axis. These successes have driven demand for true 5-axis machines with CNC controlled simultaneous motions so that more complex shapes and tool geometries can be prepared. Wet lasers using 5-axis machine tool platforms from both Makino, Japan and Willemin-Macodel, Germany are already available (Figure 19). However, these are relatively large machines whereas many diamond tools, especially single crystal tools, are quite small. It is also interesting to note that the latest PCD blank formats from Element 6 (Figure 20) for PCD milling and drilling applications are also small and these will lend themselves well to wet laser processing in 3 dimensions. For small tools, Synova has therefore developed a very compact, entry level 5-axis machine as shown in Figure 21. The machine will fit though a standard doorway and uses a software interface with which toolmakers will already be familiar. The working volume is 50mm long and 50mm diameter. The hydraulic chuck can take shafts up to 20mm in diameter. All axes are water cooled and run with a 1µm precision.

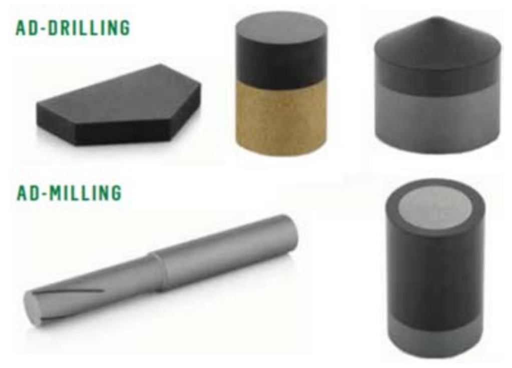

Figure 20 **– New 3D Shapes of PCD Blanks … Courtesy Element 6**

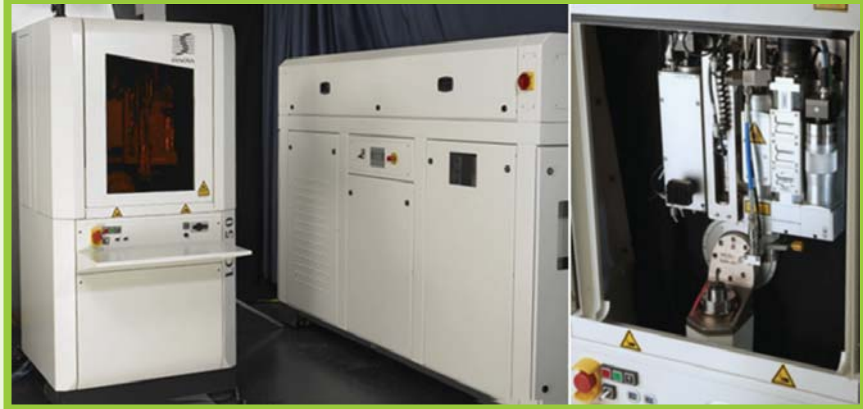

Figure 21 **– Compact 5 Axis Wet Laser and Associated Water/Laser Module for Small Diamond Tool Shaping**

CONCLUSIONS

The intense heat of a dry or gas assisted laser is a double edge sword for production managers. The heat produced allows many types of materials to be machined but this heat also introduces negative issues. A sharply focused hot spot is essential for ablation but subsequent heat dissipation and temperature gradients may also lead to problems of oxidation, a significant heat affected zone, thermal expansion problems, thermal distortion, cracking of brittle materials, hanging burrs in metals, loose debris and hot particulate splatter. In addition, dry lasers need to be constantly re-focused on undulating parts and the V shape kerf gets wider as the dry laser cut gets deeper. The wet laser reduces and often eliminates completely, these negative problems. Combining laser 'fire' with a hair-thin jet of water improves laser cutting significantly. Other industries have already discovered this to be true. Now that 5- axis machines are available, the diamond tool industry can also benefit because for laser machining of hard materials: **"wetter is better".** ■

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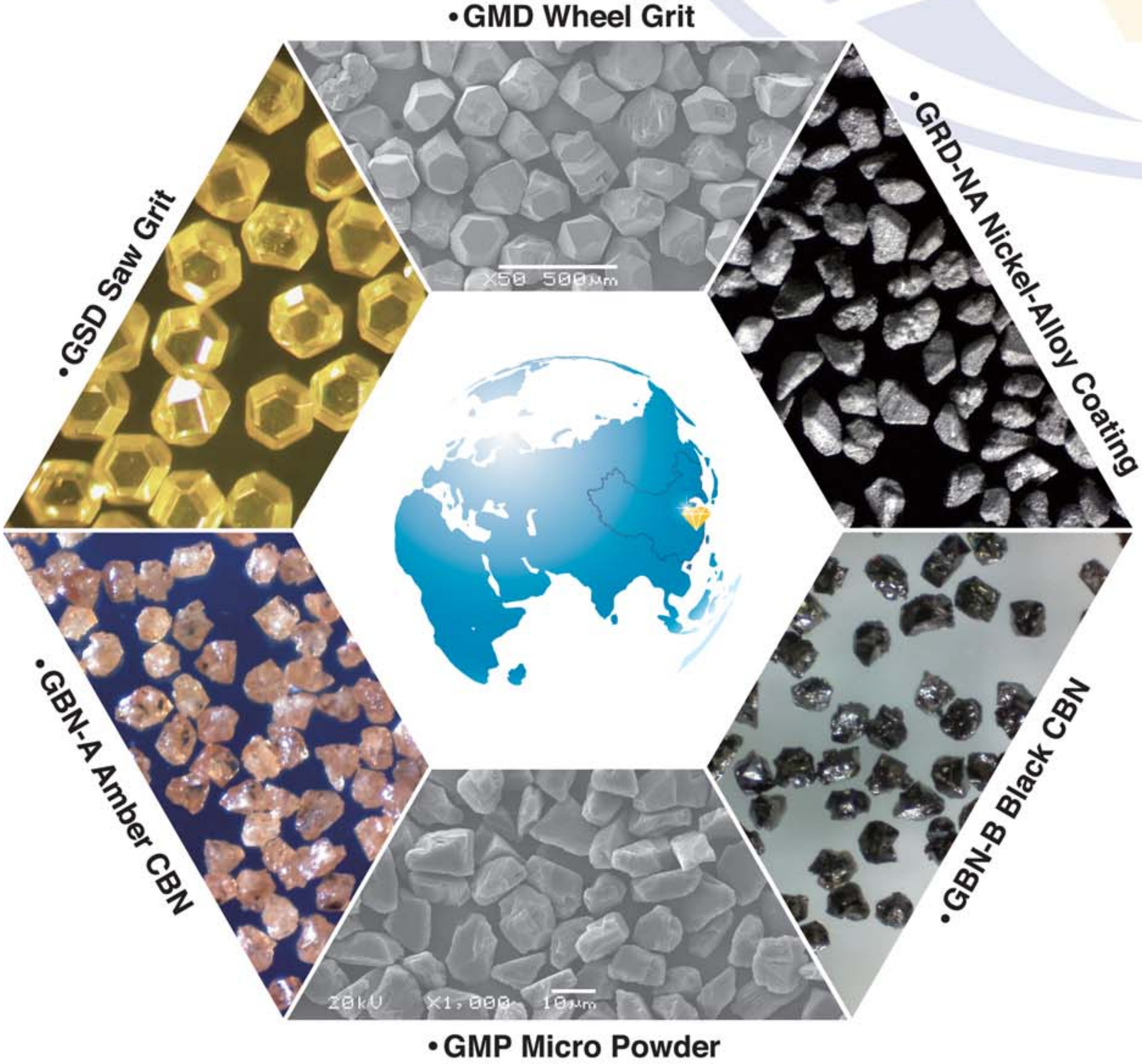

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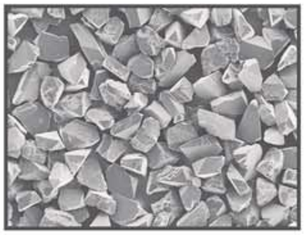

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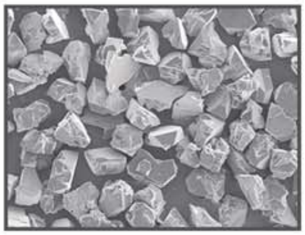

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Superabrasive Materials, Principles and Applications - Course Review

November 17 & 18, 2015 the Industrial Diamond Association of America held another Superabrasive Materials, Principles and Applications Course at the YG-1 Advanced Manufacturing Center in Charlotte North Carolina. The course featured leading instructors with a wide range of expertise covering topics from aerospace material processing to automotive applications.

The two day course covered workpiece materials and the application parameters of industrial diamond, CVD diamond, cubic boron nitride and polycrystalline tooling used in grinding and machining operations. Technical classroom presentations were punctuated with live demonstrations showing dramatic comparisons of superabrasive materials high performance to conventional materials relative sluggish productivity. Not only did attendees get to see the speed and effectiveness of superabrasives but they were able to feel the smooth surface finishes and cool part temperatures indicating no thermal damage and part integrity.

Over 70 attendees took part in this latest Education Course. The group was a diverse crosssection of industry consisting of executives, sales personnel and operators from companies that were suppliers, tool makers and end users. There were also representatives from trade schools and research facilities across the USA and other countries. Judging from the post-course survey 85-100% of the attendees had positive statements about all aspects of the course including course content, location and classroom facilities. One of the most telling data points found that 99% of the attendees surveyed said they "***would recommend this course to their colleagues and contacts***"! That is an overwhelming endorsement of this educational program!

No review would be complete without recognizing the intellectual property and leading instructors that made this course such a huge success. First and foremost a sincere thank you to YG-1 Advanced Manufacturing Center and their personnel for hosting this course especially **SHANE HOLLENBAUGH**, IDA Director and Director of Business Development, Global Product Manager PCD for YG-1and **JASON WELLS**, Director of Technical Services for YG-1 who committed their time and energy to making this such a success. Next, all the member companies in the Industrial Diamond Association of America (IDA) who contributed their expertise, presentation support and knowledge to formulate the syllabus used in this course.

Special thanks to the Education Committee of **DAVID SPELBRINK**, Co-Chairman, IDA Director and Director of Sales for LANDS Superabrasives, **SCOTT RIES**, Co-Chairman, IDA Director and Vice President of Operations for West Ohio Tool, **KEITH RECKLING**, President of the IDA and Field Sales Representative for National Research Company, **ED FRANCIS**, IDA Secretary/Treasurer and Vice President of Crystallume, **TERRY KANE**, Executive Director and **KATHY KANE**, Business Manager and Meeting Planner of the Industrial Diamond Association of America

The IDA has been a driving force in education of our industry since it was established seven decades ago. From the first natural diamond used in wire drawing, set stones for drilling and in wheels for carbide grinding to the introduction of manufactured diamond, cubic boron nitride, polycrystallines and most recently CVD diamond, the IDA has been the education leader.

The attendees had the privilege to listen to expert instructors from leading companies across the industry:

DR. ABDELATIF ATARSIA, the Sales & Marketing Director at International Minicut Inc. gave an insightful lecture on the development of new machining and drilling strategies for Aerospace parts and structure for higher performance and lower cost on new materials being developed for application in aerospace components. These new materials create a wide range of processing challenges in manufacturing operations and Dr. Atarsia entertained and educated an captivated audience!

DR. JEFFREY BADGER, "The Grinding Doc" is an expert in the industrial process of grinding. He works independently as a consultant, helping companies around the world improve their grinding operations and troubleshooting grinding problems. He has worked in grinding facilities in over 30 countries. He is well known for his practical, down-to-earth, yet high-tech approach to the subject. His instruction and laboratory demonstrations were a featured session.

ED FRANCIS is currently Vice President of Crystallume and gave an outstanding presentation on CVD diamond products and application. Mr. Francis has served on the Industrial Diamond Association of America (IDA) Board of Directors. He has been involved in CVD Diamond since 1993 and machining since 1974, he currently is Secretary/Treasurer of the IDA.

DON GIESEKE is a Senior Account Mgr. for Element 6, a manufacture of PCD/PCBN, CVD/HPHT single crystal diamond, carbide wear products, PDC cutters, CBN and diamond grits/microns. Mr. Gieseke received excellent comments from the attendees on his basics of PCD 3 Dimensional technology presentation.

SHAYNE MILLER is a Superabrasives Application Engineer at Fives Landis Corp/ CITCO Tools. CITCO Tools is a premier supplier of engineered tooling solutions utilizing PCD, CVD, and PcBN superabrasives. Shayne has 5 years of experience in the cutting tool industry as a lead CNC programmer, Tooling Design Engineer, and Superabrasives Application Engineer. Recently, he is a Project Leader for Superhard Tooling Development for CITCO tools. Mr. Miller gave an impressive demonstration comparing conventional to superabrasive cutting tools.

AARON NOLAN is currently the Solids Products Manager at WORLDWIDE SOLIDS, LLC A DIVISION OF WORLDWIDE SUPERABRASIVES, LLC (WWSA). Aaron has vast industry experience holding leadership positions at Mitsui Seiki USA and Sumitomo Electric Carbide Materials Group. During that time he was responsible for PCD/PCBN cutting tools, PCD wire die blanks, specialty carbide materials, single crystal HPHT diamonds throughout North America. He is a Director for the Industrial Diamond Association of America as well as a WAI Ohio Valley Board of Director. Aaron has in-depth knowledge of the superabrasive and cutting tool market and it showed when he instructed on the basics of PcBN & PCD.

WILLIAM SHAFFER is the Owner of Conicity Technologies LLC. Mr. Shaffer worked for Kennametal Corporation, a leading global producer of cutting tools, for over 30 years. In this time, he held the titles: Engineer, Senior Engineer, and Staff Engineer and Manager of Manufacturing Systems. Mr. Shaffer pioneered brush-honing technology and received the 1982 Award of Excellence from the Abrasive Engineering Society for this development. Additionally, he has developed the technology underlying nine other patents in the field of cutting tools. Mr. Shaffer is regarded as an expert in cutting tool edge prep and graciously shared his expertise and techniques for superabrasive cutting tool edge prep.

DAVID SPELBRINK, Education Committee Co-Chairman attended Rutgers University and has been in the superabrasives industry since 1997 and presently serves as Director of Sales for LANDS Superabrasives as well as his role on the natural diamond side of the superabrasives industry with Lieber & Solow. He has recently co-authored an article on the state of natural diamond for industrial applications and co-authored an article on pellet grinding on glass a few years back. David has served on the IDA board for 7 years and, along with Scott Ries, has headed both the INTERTECH and now the Education committees. David's knowledge of superabrasive grains & principles of bond systems received high marks from all attendees.

ATTILA SZUCS is the President of Advanced Superabrasives Inc. and gave an excellent demonstration on his company's truing & dressing machine of how to properly true and dress a cbn wheel. This process is required to prepare a wheel for use in a manufacturing operation and properly done results in a productive operation delivering exceptional parts with no thermal damage and good surface finish. Mr Szucs has been a part of projects such as the Mars Rover Grinding Project as well as other numerous high tech adventures. He has also been published in a book called Grinding in Extreme Environments, which was released in 2010. ■

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GUEST EDITORIAL

Are We Losing Half Our Talent Due to Outdated Education Methods?

New teaching styles are needed to encourage young men to pursue college degrees.

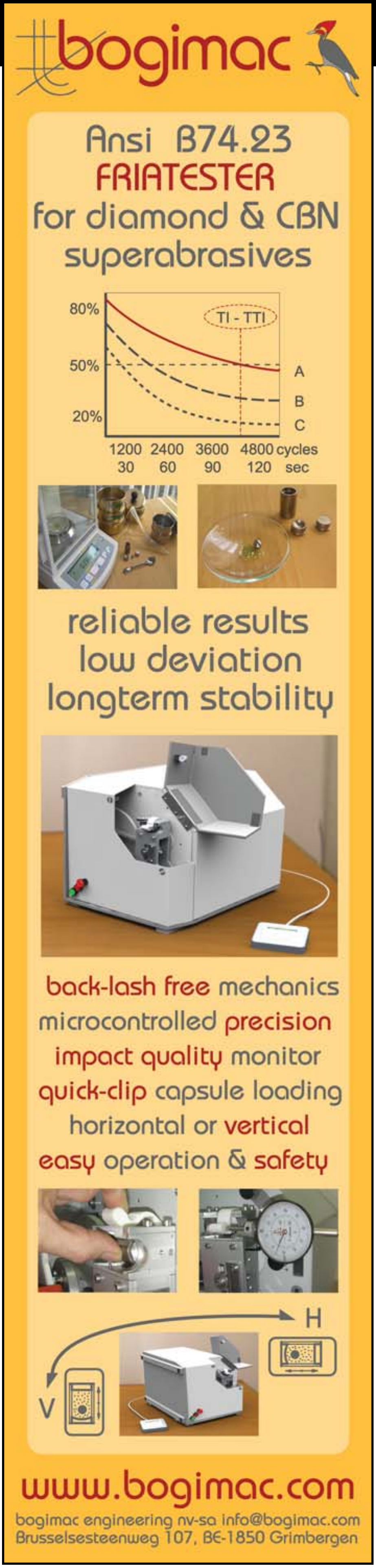
By: ADRIENNE SELKO
Senior Editor, Material Handling & Logistics News

In a time when our future workforce will determine the economic strength of our country, I'm concerned that the number of young men seeking higher education is dropping. ***As that potential pool of employees shrinks, employers will face continued hardship in finding qualified workers***. According to the White House Council of Economic Advisors, if males graduated college in the same proportion as women, there would be about 14% more college graduates each year. As it stands now, though, we could be facing a shortfall of two million workers over the next decade ... What is going on? One explanation, offered by Thomas DiPrete and Claudia Buchmann, sociology professors at Columbia and Ohio State, is that grade schools aren't boy-friendly, or to put it another way, schools aren't teaching the way boys like to learn. Some school districts, though, are changing their teaching styles. For instance, Michael Gurian and Kathy Stevens of the Gurian Institute are piloting a two-year program in the Missouri school system that is "boyfriendly." Some successful techniques used in the classroom include:

- **Classroom methodology includes project-based education in which the teacher facilitates hands-on, kinesthetic learning**. The more learning is projectdriven and kinesthetic, the more boys' bodies will be engaged in learning – causing more information to be retained, remembered and displayed on tests and assignments.
- **Teachers move around their classrooms as they teach**. Instructors' physical movement increases boys' engagement, and includes the teacher leading students in physical "brain breaks" – quick, one-minute brainawakening activities—that keep boys' minds engaged.
- **Students are allowed to move around as needed in classrooms, and they are taught how to practice selfdiscipline in their movement**. This strategy is especially useful when male students are reading or writing – when certain boys twitch, tap their feet, stand up, or pace, they are often learning better than if they sit still, but teachers are often not trained in innovating toward more movement in classrooms.
- **Teachers increase the use of graphics, pictures and storyboards in literacy-related classes and assignments**. When teachers use pictures and graphics more often (even well into high school), boys write with more detail, retain more information and get better grades on written work across the curriculum.
- **Teachers provide competitive learning opportunities, even while holding to cooperative learning frameworks**. Competitive learning includes classroom debates, content-related games and goal-oriented activities; these are often essential for boy-learning and highly useful for the life success of girls, too. With this new emphasis on understanding that hands-on learning is essential to how boys learn, some high school programs are looking at manufacturing as the tool to attract boys to future education. The skills they require will address the missing link that DiPrete and Buchmann found, which is that "boys have less understanding than girls about how their future success in college and work is directly linked to their academic effort in middle school and high school." Making that connection clear, they argue, could go a long way toward closing the gender gap in higher education.

These hands-on programs are popping up across the country. Davenport, Iowa, established a ***High School Advanced Manufacturing Career Academy*** that will allow 20 Iowa Quad City high school students to earn college credit and in some cases earn certifications. Another program in Illinois (Palatine-Schaumburg district) offers advanced manufacturing classes. Created with Harper College and area companies, high school students can earn 21 hours of dual credit at Harper, which can then help them complete simultaneous internships at area companies. Mark Hibner, an applied technology teacher at Palatine High, hits the nail on the head when he observes that "most students who start the program don't do so with a firm intention of pursuing a manufacturing career, but perhaps because they saw something cool a friend of theirs made in class." It is capturing the interest of boys in our educational system at a young age, and giving them skills that are applicable in the real-world, that will ultimately help convince young men to continue on to the university level.

This article originally appeared in Material Handling & Logistics (January 2016), a Penton publication, and is used with permission.



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Nanosecond laser processing of diamond materials

Mr. Jan-Patrick Hermani; Dr.-Ing. Michael Emonts; Prof. Dr.-Ing. Christian Brecher
Fraunhofer IPT

ABSTRACT

Laser processing of synthetic diamonds for tooling application has been industrially established since the early 2000's. Though there are many publications dealing with the interaction between laser radiation and diamond materials using scientific laser sources, there are no comprehensive studies available for achievable ablation rates using industrially wide spread nanosecond laser sources. This paper will focus on the investigation of laser ablation results for various monocrystalline and polycrystalline diamond materials using a NIR laser source with maximum pulse energy of 1 mJ. Single pulse ablation results for different laser parameters show that the ablation depth for polycrystalline diamonds is limited by absorption of laser radiation in the plasma plume. The plasma plume is visualized by high speed photography and correlated to the ablation results.

The nanosecond laser ablation process for monocrystalline diamonds strongly depends on the impurities, especially the nitrogen content. For high-purity monocrystalline diamonds spectroscopy analysis show almost no NIR-absorption. As there is no multi-photon absorption for nanosecond laser irradiation ablation can only be achieved by use of an absorption coating. Experimental results show that the initial absorption of laser radiation in the coating leads to thermally-induced formation of a graphite layer on top of the diamond. This graphite layer enables absorption of NIR laser radiation and further ablation without the need of an additional absorption coating.

INTRODUCTION

The outstanding properties of cutting tools made of diamond materials make these tools ideal for machining light metals, FRP and wood in economically efficient operations. However the degree of hardness and the level of wear resistance present enormous challenges throughout the processes involved in manufacturing the cutting tools. Low material removal rates and heavy abrasive disk wear make conventional finish machining operations through grinding, both costly and time consuming. Laser processing offers the big advantage to effectively run without any tool wear.

Synthetic diamonds are produced either by high pressure high temperature processing (HPHT) or chemical vapor deposition (CVD). Both manufacturing techniques are able to produce monocrystalline diamonds (MCD) as well as polycrystalline diamonds (PCD). Most diamonds used for tooling applications are HPHT-PCD. Figure 1 shows a typical process chain for a diamond tool manufacturing process. PCD blanks manufactured by HPHT usually are diskshaped consisting of a cemented carbide substrate with a PCD top layer. Single PCD cutting inserts are manufactured by cutting the PCD blank into pieces by either wire electrical discharge machining or laser cutting. The cutting process results in a thermally affected rim zone which has to be removed before using the tool. In a next step the cutting inserts are brazed on tool holders. The brazing process causes dimensional and angular errors which also have to be removed to achieve a high shape accuracy of the diamond tool. In a final finishing step the affected rim zones as well as the brazing errors have to be removed and the macro geometry (corner radius, clearance angle) and the micro geometry (cutting edge, chip breaker have to be manufactured.

Conventional machining techniques for the finishing step are grinding as well as electrical discharge machining. Since the early 2000's laser processing has been industrially established as finishing technique. Single laser pulses are positioned next to each other creating grooves into the material. By repeating groove by groove whole layers can be removed. The PCD material allowance is removed layer by layer. The first layers are usually removed using a parameter setting with high ablation rates and poor surface quality. The last layers are removed with low ablation rates but high resulting surface quality. From the laser point of view there can be distinguished between two different processes: ultrashort pulse laser ablation and short pulse laser ablation. Ultrashort pulse laser ablation refers to a process with pulse duration of less than 10 picoseconds. Within this period of time the laser beam material interaction is limited to interaction between electrons. A heat transfer and thermal equilibrium between electrons and crystal lattice takes place after approx. 1 nanosecond. The energy is deposited into the material without heating up the material in a macroscopic scale. Short pulse laser ablation refers to pulse duration in the nanosecond time scale. The energy is deposited into the material while the material is heating up, melting and evaporating (see figure 2).

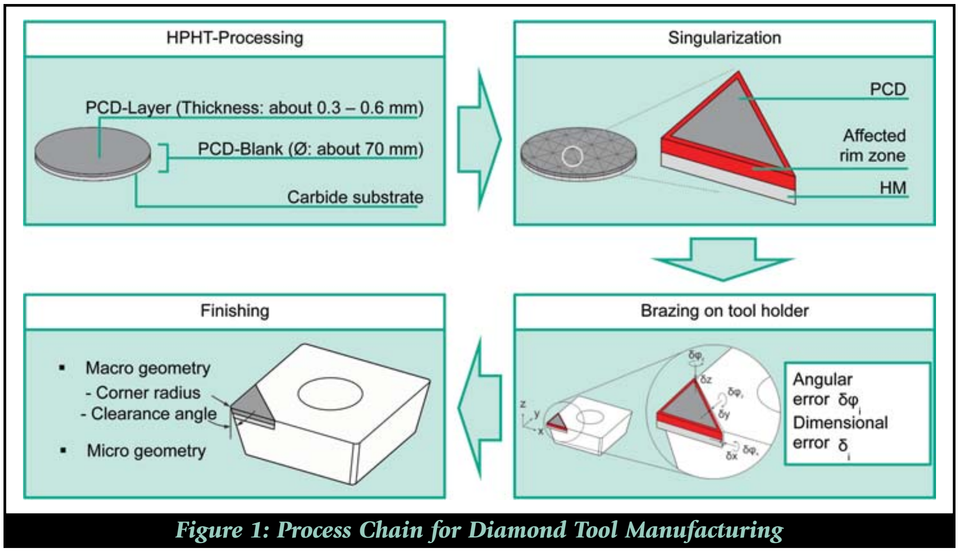

Figure 1: Process Chain for Diamond Tool Manufacturing

The absorption characteristics of short pulse and ultrashort pulse laser

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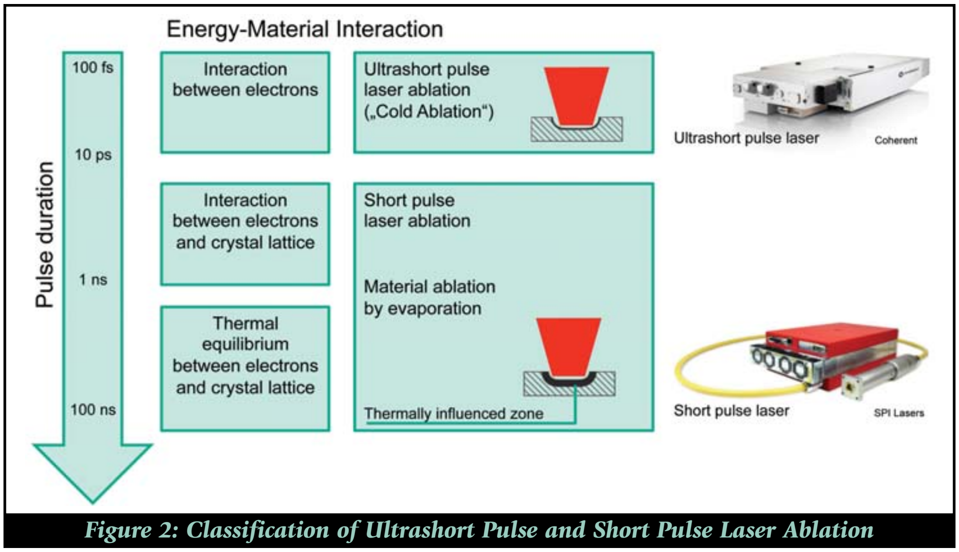
Energy-Material Interaction
Pulse duration
100 fs
10 ps
1 ns
100 ns
Interaction between electrons
Interaction between electrons and crystal lattice
Thermal equilibrium between electrons and crystal lattice
Ultrashort pulse laser ablation („Cold Ablation")
Short pulse laser ablation
Material ablation by evaporation
Thermally influenced zone
Ultrashort pulse laser
Coherent
Short pulse laser
SPI Lasers

Figure 2: Classification of Ultrashort Pulse and Short Pulse Laser Ablation

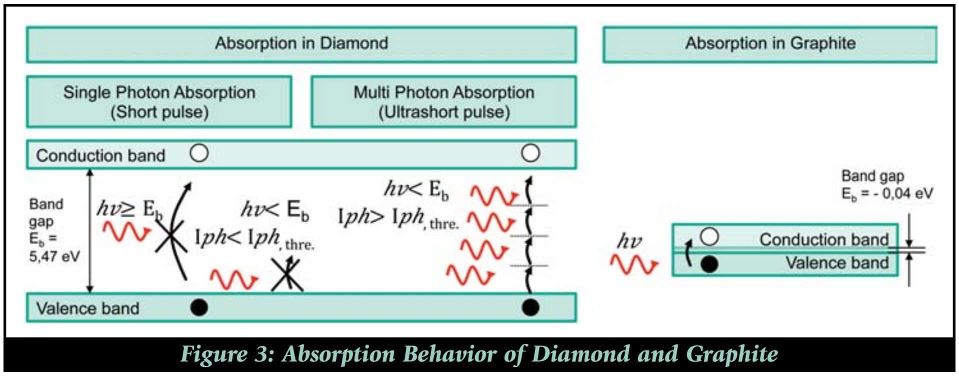

Figure 3: Absorption Behavior of Diamond and Graphite

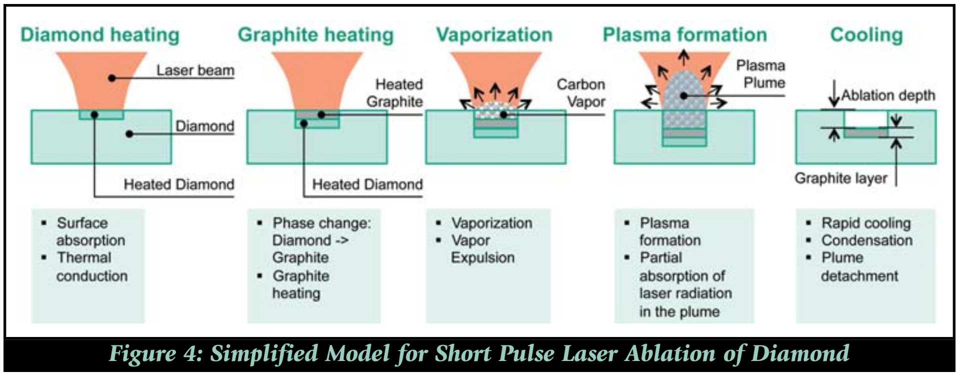

Figure 4: Simplified Model for Short Pulse Laser Ablation of Diamond

radiation in diamond materials differ considerably. Basic requirement for absorption of laser radiation in pure, monocrystalline diamond is an excitation of electrons from the valence band, which requires bridging the bandgap (figure 3). Diamond has a very high bandgap Eb between the valence band and conduction band approximately 5.5 eV. The required energy for bridging the bandgap may be provided by individual photons only if the wavelength is less than approximately 225 nm (UV). However, the laser sources used for material processing have a wavelength of about 1064 nm (NIR) or 532 nm (green). In an ideal, pure diamond laser radiation of wavelength 1064 nm or 532 nm cannot be absorbed. However, absorption in real diamonds is enabled by imperfections, additives, grain boundaries or gas inclusions. In the case of multiphoton absorption an electron can be excited by multiple photons. For multiphoton absorption, a high temporal and spatial photon density Iph is required. Focused laser radiation of ultrashort pulse laser systems usually fulfills these requirements. In contrast to diamond graphite has advantageous absorption properties. Valence and conduction bands are close to each other and overlap at some positions, resulting in negative values for the band gap. Therefore, graphite is considered as a material with good absorption properties. Depending on surface properties and temperature the absorption levels up to 98% can be obtained. For this reason, graphite is often applied as a powder or spray in laser materials processing to improve the absorption properties of highly reflective materials.

Model for Short Pulse Laser Ablation of Diamond

As mentioned above short pulse laser radiation is absorbed in diamond by imperfections, additives, grain boundaries or gas inclusions. The energy is deposited into the surface of the diamond material and is generating heat. The heat is transported into the depth by thermal conduction. After reaching the graphitization temperature of about 2000 °C the carbon phase changes from diamond to graphite. After further energy input by laser irradiation the graphitized surface layer reaches vaporization temperature at around 4000 °C. The graphite evaporates and carbon vapor expands with high pressure. As a consequence of the evaporation laser radiation is absorbed by carbon particles in the plume leading to plasma formation. Further laser radiation is partially absorbed in the plasma plume. After laser irradiation has stopped a crater has formed in the material. On the bottom of the crater a graphite layer can be found.

The thickness of the graphite layer again depends on the pulse duration. Kononenko et al. have demonstrated an analytical and experimental relation between pulse duration and thickness of graphite layer (see figure 5). For ultrashort pulse laser ablation the thickness of graphite layer is proportional to the absorption properties of graphite. There is no relation between pulse duration and graphite thickness due to the fact that heat conduction starts after the end of the laser pulse (as shown in figure 2). For short pulse laser processing the thickness of graphite depends on the pulse duration and thermal properties of graphite. For laser pulses of 200 ns pulse duration the graphite layer can reach a thickness of 1 µm. The Fraunhofer IPT has experimentally proved the relation (transmission electron microscopy image on the right side in figure 5) for a pulse duration of 220 ns. After laser processing of PCD a graphite layer with a thickness of 0.8 µm was found by analyzing a thin lamella prepared by focused ion beam (FIB).

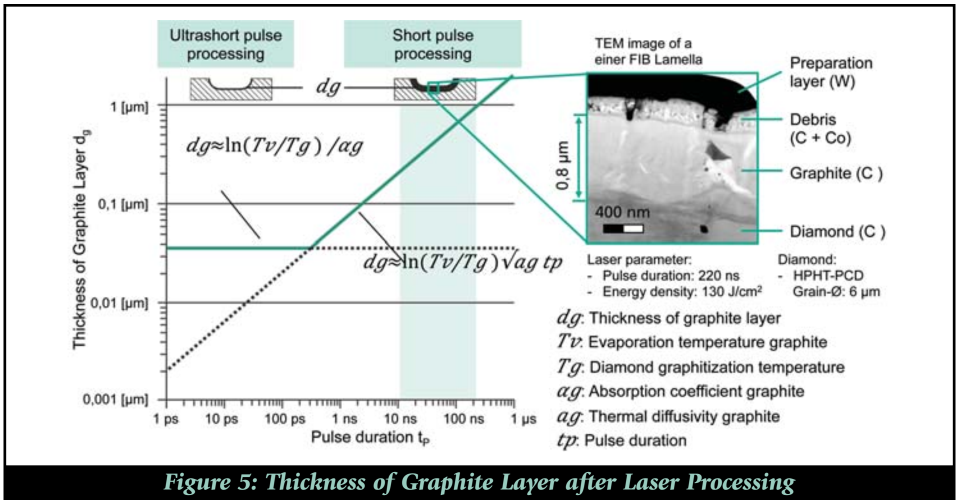

Figure 5: Thickness of Graphite Layer after Laser Processing

Ablation Results for Polycrystalline Diamond

Different polycrystalline diamond materials were investigated after single pulse laser irradiation under variation of pulse energy (results see figure 6). It was found out that the ablation depth for cobalt-free CVD-PCD is higher than for cobalt-containing HPHT-PCD. The reason for the differences between the materials is the different thermal conductivity. The thermal conductivity for medium grained HPHT-PCD is between two to four times lower than for CVD-PCD. Low thermal conductivity leads to a fast heating at low values of fluence and consequently to evaporation and ablation even at low values of fluence. For higher values of fluence the heat cannot be conducted fast enough into the depth of the material to reach evaporation temperature. High thermal conductivity leads to a higher ablation threshold. For the parameters shown in Figure 6 ablation of CVD-PCD requires a fluence of 20 J / cm2. The achievable ablation depth at higher values of fluence is higher than for HPHT-PCD due to better thermal conductivity.

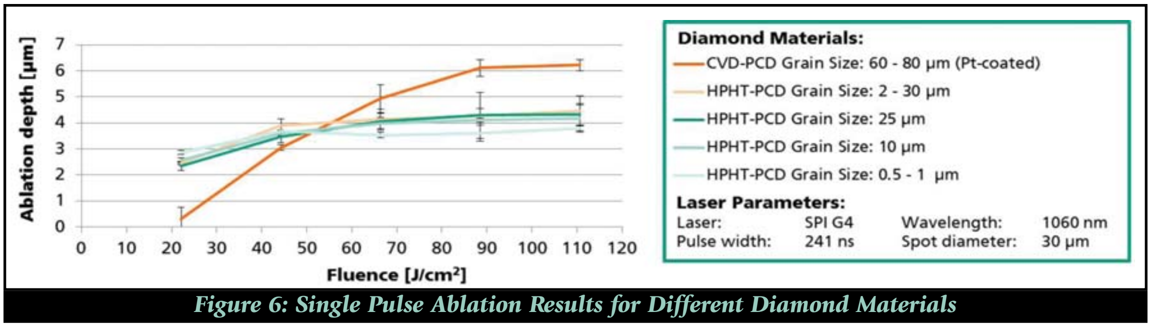

Figure 6: Single Pulse Ablation Results for Different Diamond Materials

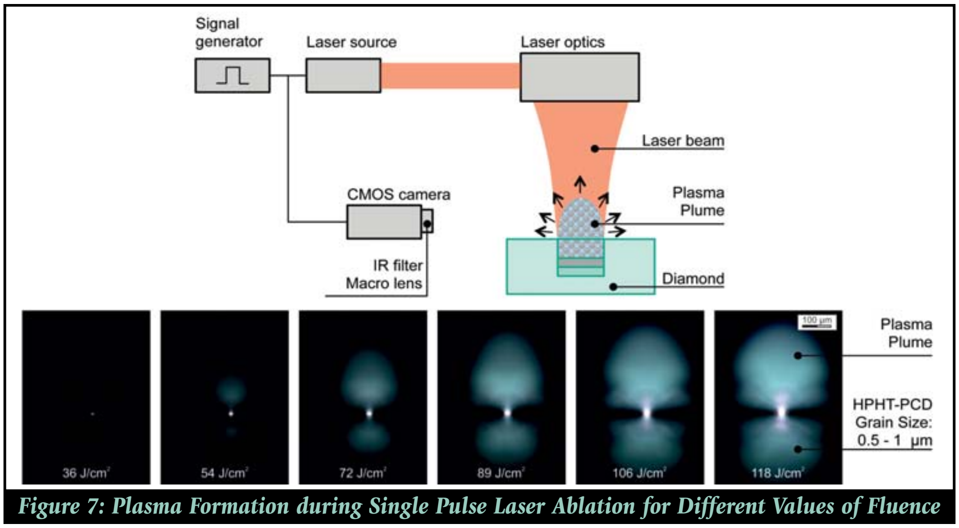

Figure 7: Plasma Formation during Single Pulse Laser Ablation for Different Values of Fluence

It can be further observed that the ablation depth is limited for higher values of fluence for all PCD materials. As shown in figure 4 laser radiation is absorbed in the plume after material has been evaporated. This effect is further analyzed by two experiments. First experiment (figure 7) shows the plasma formation during single pulse laser ablation for different values of

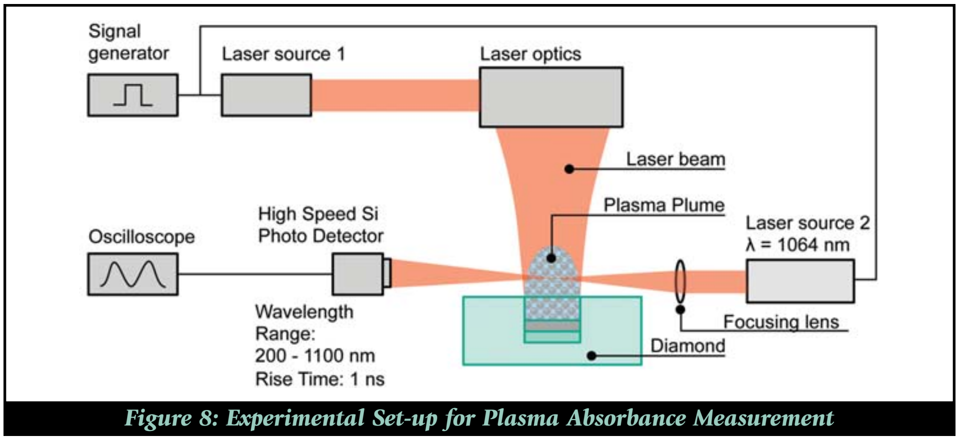

Figure 8: Experimental Set-up for Plasma Absorbance Measurement

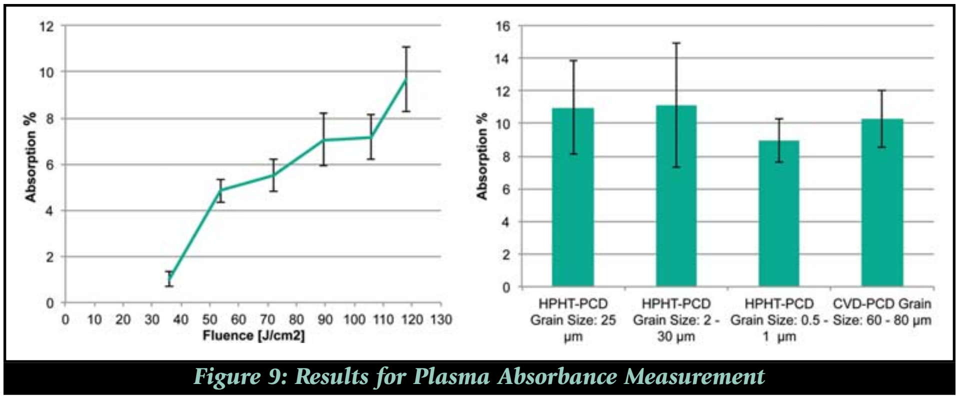

Figure 9: Results for Plasma Absorbance Measurement

fluence. For that purpose a CMOS camera is installed and synchronized with the laser source. It is obvious that the size of plasma plume is scaling with fluence. The plume size variation for different diamond materials is insignificant (not shown).

In a second experiment a second laser source is used to measure the absorption in the plasma plume (figure 8). The second laser source is horizontally installed and the laser beam is focused into the plasma. On the other side of the plasma a high speed photo detector is installed to measure the laser power transmitted by the plasma plume.

The absorption of laser radiation in the plasma is increasing with increasing values of fluence of laser source 1 (figure 9). For different diamond materials the absorption of laser radiation in the plume is insignificant.

Summing up the short pulse laser ablation behavior of different PCD materials depends on the thermal properties of the diamond. Higher thermal conductivity leads to higher achievable ablation depth. The ablation depth is limited by plasma formation and absorption of laser radiation in the plasma plume. Absorbance of laser radiation in the plume has to be avoided to achieve high process efficiency.

Application

The Fraunhofer IPT uses optimized ablation strategies for a novel approach for diamond tool processing: laser roughing. In laser roughing operations, a laser beam minimizes the PCD material allowance required by the manufacturing process swiftly, without causing any tool wear. Only a few micrometers subsequently need to be finished by grinding in order to achieve the required surface qualities. The combined process reduces the finish machining effort by more than 50 percent and also lowers the

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The Fraunhofer IPT is developing ways of integrating laser roughing operations within the process of manufacturing PCD cutting tools. We have many years of experience in laser system engineering and in manufacturing special purpose machinery geared to facilitating optimum development of new production processes. The Fraunhofer IPT has pioneered a PCD roughing laser module which can be customized to meet the requirements of PCD cutting tool manufacturers: fully automated laser processing of PCD cutting tools, flexible adaptation to required cutting edge geometries, encapsulated system to ensure laser safety, low energy consumption, compact design and low acquisition cost.

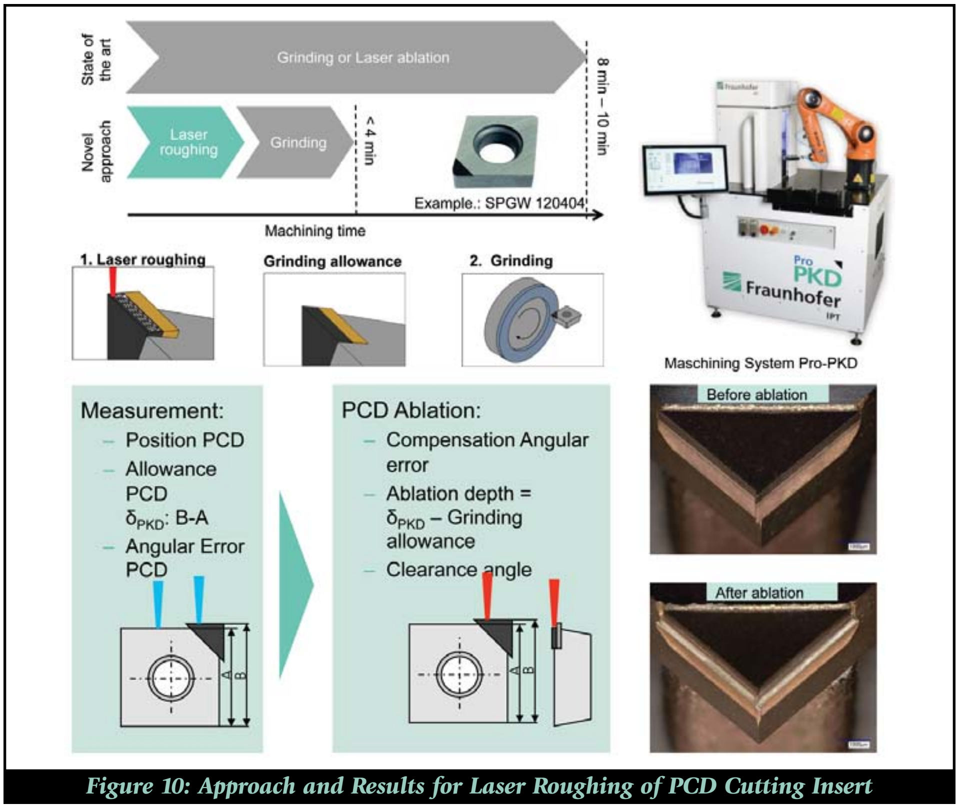

Figure 10: Approach and Results for Laser Roughing of PCD Cutting Insert

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6 Axis Green Laser Sawing & Shaping for Hard Materials

By: BEN HAKMAN, OGI Tech Inc.

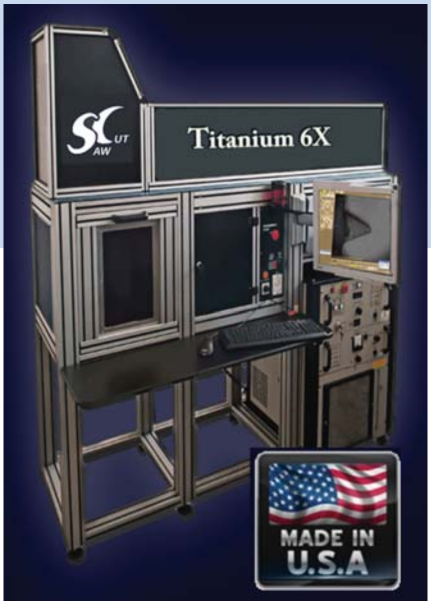

FIGURE 1:* *Titanium 3X – 3 Axis American 532nm Green Laser Sawing System part of the new OGI Titanium Line of Laser Sawing Systems

ABSTRACT

Green Laser Sawing is an essential process in the hard materials industry today, from Research, Product Development, Coring and Seeding CVD and HPHT to Shaping, Edging and 3 Dimensional Sawing Applications for all hard materials. With the increase in demand for various tools and Industrial applications, Multiple Axis Sawing is becoming more and more in demand and with the combination of the correct Laser System in place.

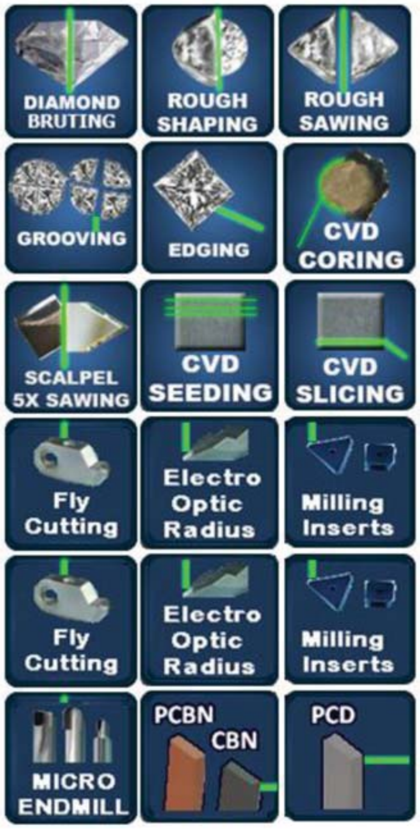

FIGURE 2:* *Titanium Applications

1. Introduction

OGI Titanium 6X

The Titanium Technology is the next and latest in Green Laser Sawing Innovation by OGI Systems continuing the footsteps of the OGI Systems 8 Year SawCut Technology. OGI Systems - a 25 Year old Pioneer & Leader in Diamond Laser Technology – from Laser Marking, Laser Inscription, Laser Mapping and Laser Sawing to 3D Scanning and Imaging The Titanium 6X is the first of its kind, was specially developed for high capacity around the clock Laser Sawing and Shaping with precise, safe and extremely fast laser sawing and processing of Natural Diamonds, PCD, CBN, PCBN, CVD, Gemstones and HPHT for Gem, IT and Industrial Applications.

The Titanium 6X is the first 6 Axis Laser Sawing System for Hard Materials with Industrial and Gem Applications to Simultaneously Process

14 x different units of Hard Materials in – 6 Axis Mode

38 x different units of Hard Materials in – 3 Axis Mode

With sawing capabilities of product ranging from 0.2mm to 70mm.

ENABLING

- Diverse sawing applications such as Milling Inserts, Micro Endmills, Fly Cutting Tools, Radius Tools, Contact Lenses, Surgical Diamond Knives and much more.
- Advances 3 Axis Mode for Coring Seeding and Slicing
- Smooth Sawing Surface in all directions including corners
- Consistent thickness with accordance to the customers' requirements

IN ADDITION TO BEING EXTREMELY

- Safe to use regardless to the materials or sawing methods of the manufacturer
- User Friendly, reliable and easy to operate
- Maintenance Free

2. Applications

The Titanium line has an advanced shape editor enabling a variety of applications.

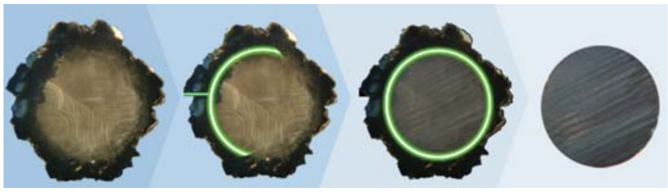

FIGURE 3:* *CVD Coring

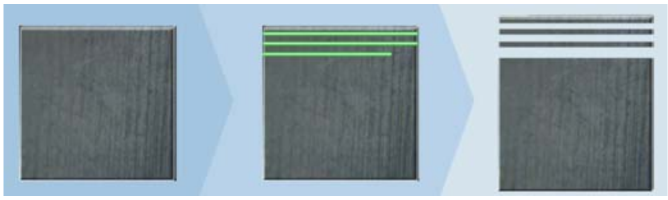

FIGURE 4:* *CVD Slicing and Seeding

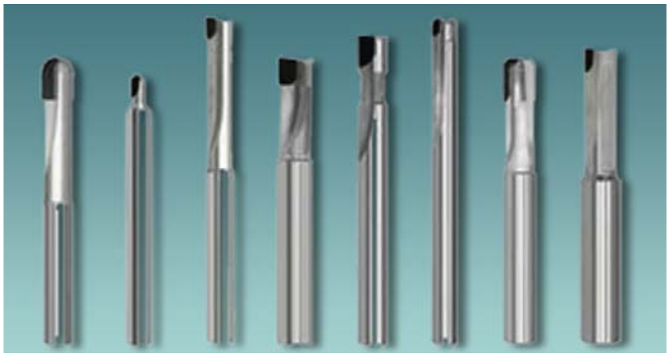

FIGURE 5:* *Micro Endmills

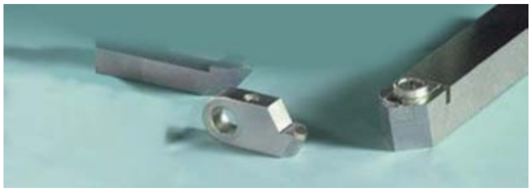

FIGURE 6: *Fly Cutting Tools*

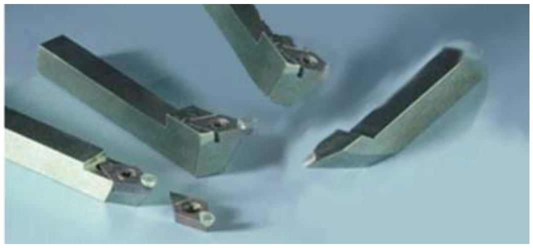

FIGURE 7: *Electro Optic Radius Tools*

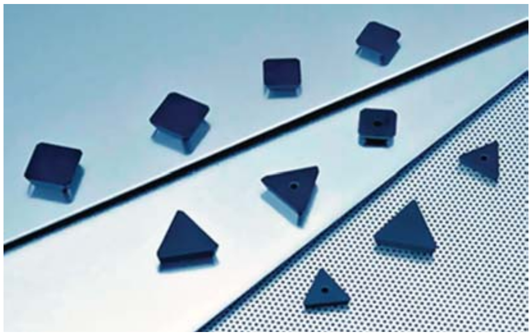

FIGURE 8: *Milling Inserts*

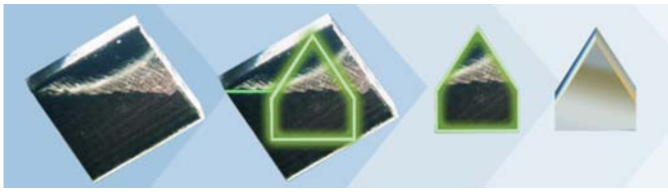

FIGURE 9: *Surgical Diamond Knives*

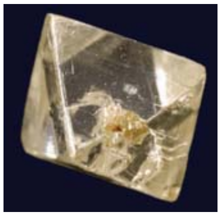

FIGURE 10: *High Stress Polaris Diamonds*

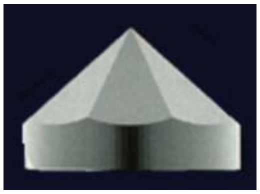

FIGURE 11: *Blocking Pre or Post HPHT*

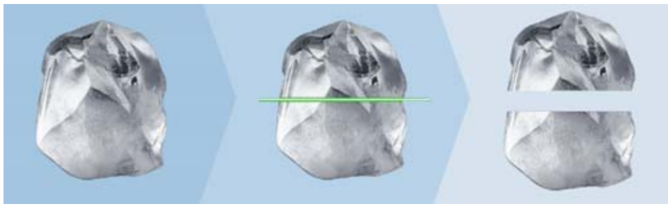

FIGURE 12: *Rough Diamonds Sawing*

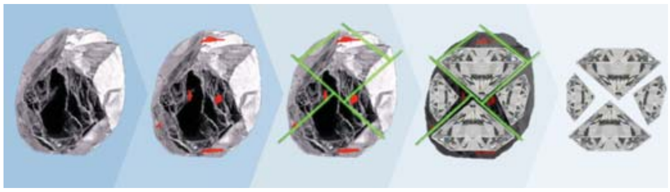

FIGURE 13: *Rough Diamonds Mapping & Sawing*

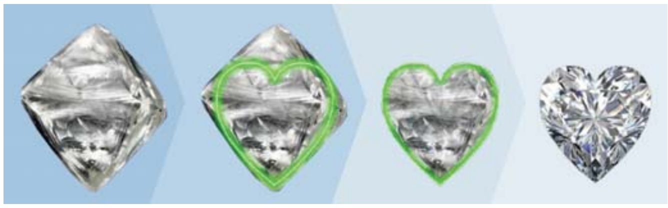

FIGURE 14: *Rough Diamonds Shaping*

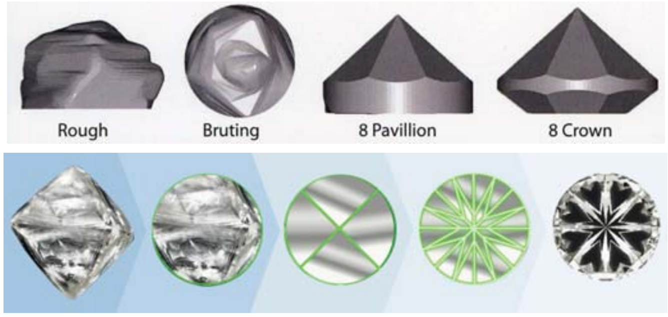

FIGURE 15: *Diamond Bruting*

3. Precision

Laser Sawing Precision requires not only a precise steady Laser but an advances 3D software that supported advanced accessories like 2D and 3D HD Scanners as a Laser Marker and SawLiner for ultimate Precision.

Examples on Figure 9, 14, 15, 16, 17 & 18

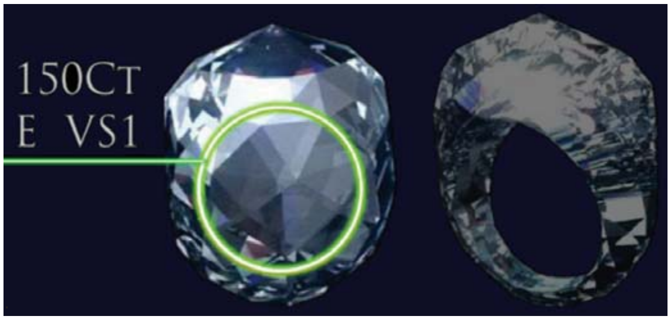

FIGURE 16: *150 Carat the Shawish Jewelry*

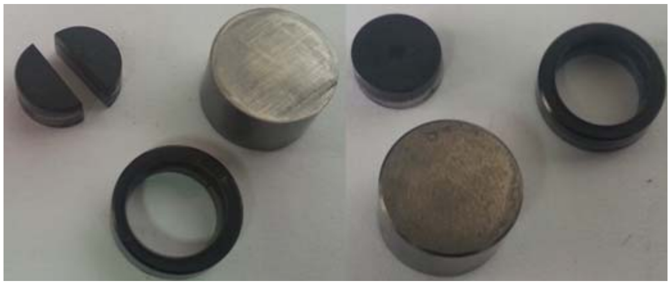

FIGURE 17: *PCBN & CBN tooling*

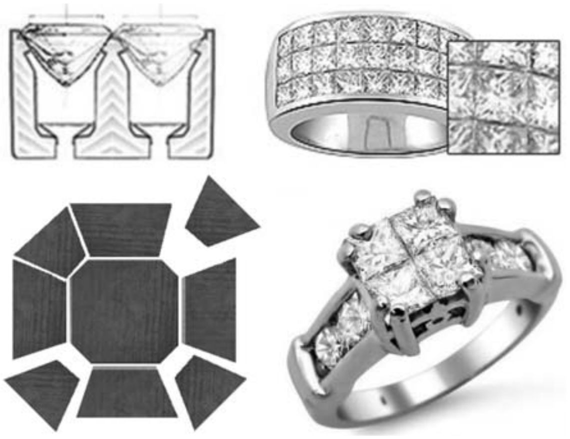

***FIGURE 18:* Grooving for invisible settings**

4. Surface Quality

Since the beginning of Laser Sawing Hard Materials starting with Diamonds the Industry standard was Sawing in Ziz-Zak with a Laser angle creating an un-necessary surface groove and Burn Marks that require additional polishing which would add to processing time as larger weight loss, today there are Laser Technologies that use parallel Laser Sawing with the addition of Lubricants or Cooling agents sacrificing on sawing speeds and work flow , the Titanium Technology is using close to parallel sawing without any Lubricants or Cooling agents with perfect smooth surface not sacrificing on sawing time or weight loss.

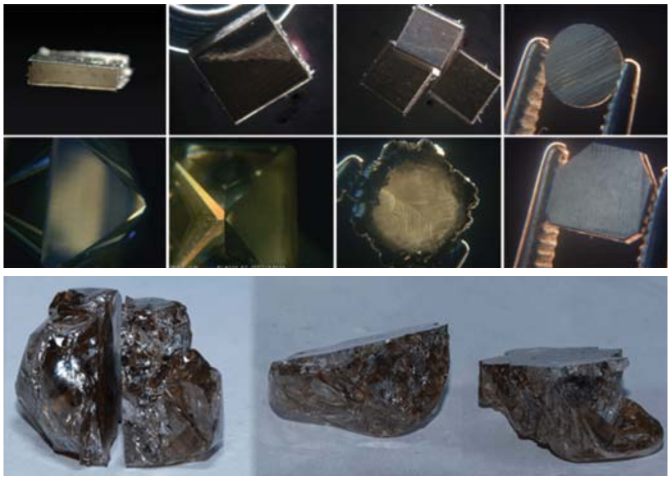

***FIGURE 19:* Surface Examples**

5. Speed and Efficiency

Laser Sawing speed time is calculated not only by the time a Laser System manages to finish Sawing the product but:

- Ability to Saw around the clock 24-7 Year Round like the SawCut/Titanium
- How user friendly and efficient is the software controlling the Laser System for ultimate production flow like the OGI 25 Years of Advanced Laser Software
- Large Sawing Chamber for easy access Like the Titanium 60x50x60Centimeters Sawing Chamber
- Supporting Advanced Accessories to expedite Sawing time like OGI 2D & 3D Scanners with STL output with Laser Marking and SaLiner utilizing 180 degree rotating Cassettes simultaneously processing multiple products at the same time
- Interruptions due to System Maintenance as all Laser Systems require a Daily, Weekly, Monthly or Quarterly attention, if it is Maintaining a constant operation of the Cooling System, Room Temperature, Filter Cleaning, Diza Cleaning, Maintaining Water Purification Levels to Avoid Optical Diversion, Internal Hardware Maintenance and Functionality in a Production Factory Environment with the Titanium's Built In Self Cleaning Filtration and Monitoring System the OGI SawCut/Titanium are Maintenance Free

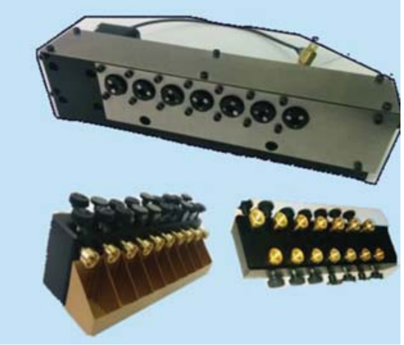

***FIGURE 20:* Sawing Cassettes**

6. Cost Efficiency

Laser Sawing Systems require additional unnecessary Expenses like

- Monthly Technician Visits – OGI Titanium is Maintenance Free
- Additional Electric Costs due to 24 Hours a Day Air Conditioning or Laser Cooling Systems – OGI Titanium has an internal thermostat that enables a small temperature range requirements as when the system is off cooling is not necessary
- Large Size Systems Occupying Large Work Areas Titanium 6X is Compact L168cm X H172cm x W85cm

***FIGURE 21:* 4 OGI Lasers in a Small Room**

7. Accessories

SCANOX Marker HD

Using the latest in High Definition 3D Technology the Scanox Marker enables not only a Dual Laser Mapping for a perfect 3D CAD output to the Titanium Shape Editor but Laser Making of Hard Materials for easy and fast sawing with end product size and weight predictions for Product under 32mm

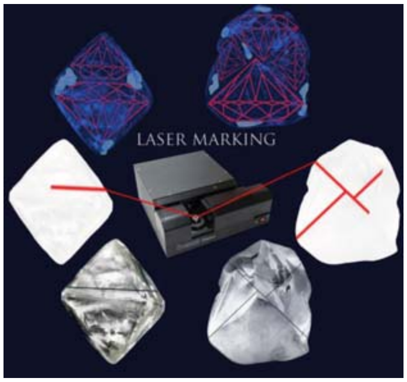

***FIGURE 22:* Scanox Marker**

GemScribe X

Laser Inscription System for Diamonds and Hard Materials, Serial Numbers, Images and Fonts.

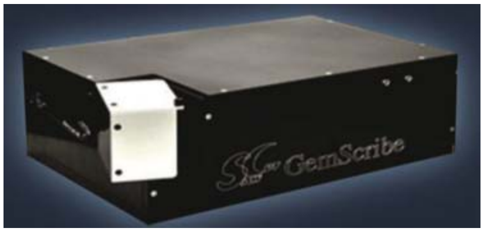

***FIGURE 23:* GemScribe X**

HD SawLiner

A set up station that aligns the product in optimal precise position for Sawing.

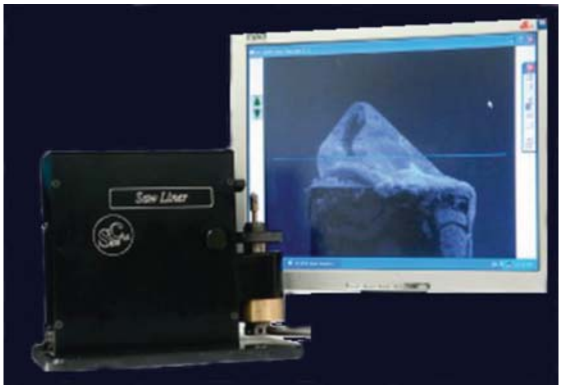

***FIGURE 24:* SawLiner**

CVD Sorter

2D 1.2 Second Anlyzer for Sorting Hard Materials as Clowning 2D STL to the Titanium Shape Editor.

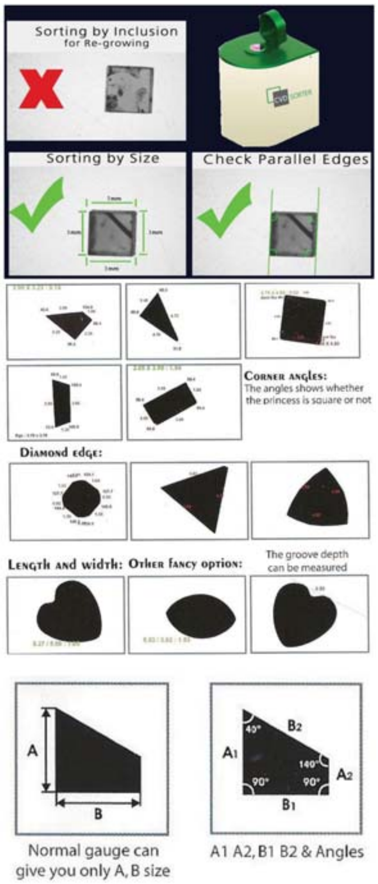

***FIGURE 25:* CVD Sorter**

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8. Hardware Specification

TECHNICAL SPECIFICATIONS

Dimensions:	168cmL x 172cmH x 85cmW
Weight:	420 kg (926 lbs)
Voltage:	220V

LASER PARAMETERS

Laser type:	Pumped by Diode
Wave length (nM):	532
Type ND:	YAG
Laser Medium ND:	YAG Crystal
Transverse Mode:	TEM00
Average Power @5Khz (W):	10
Pulse to pulse stability (%rms):	2%
Pulse with, nominal (ns):	90
Beam Diameter, nominal (mm):	1
Polarization:	Linear
Beam quality (M^2):	1, 2
Electrical Power:	220 ac, 1-phase, 50/60Hz, 16

LASER RESONATOR

- Laser medium Nd: YAG crystal
- This laser unit has been developed for its specific use in the diamond industry.
- Long pulse configuration, Constant peak power configuration at set frequencies.
- 100W powerful and stable
- TEM00 mode, Higher beam quality and stability

AUTOMATION AND MECHANICAL PARAMETERS:

- Axis Travel (XYZ): 200 mm x 200mm x 50 mm
- Rotating axe, 360 degree
- Swing axe, the angle can move +/- 110 degree
- Optimize XY motion table for best performance
- Linear motor technology with performance matched mechanical elements to provide high acceleration, high velocity, and quick settling with accurate highly repeatable positioning.
- High Strength Aluminum Body
- Square Rail Linear Bearing
- High Efficiency Ball screw Drive
- Square Rail Linear Bearing
- High Efficiency Ball screw Drive
- Square Rail Linear Bearing

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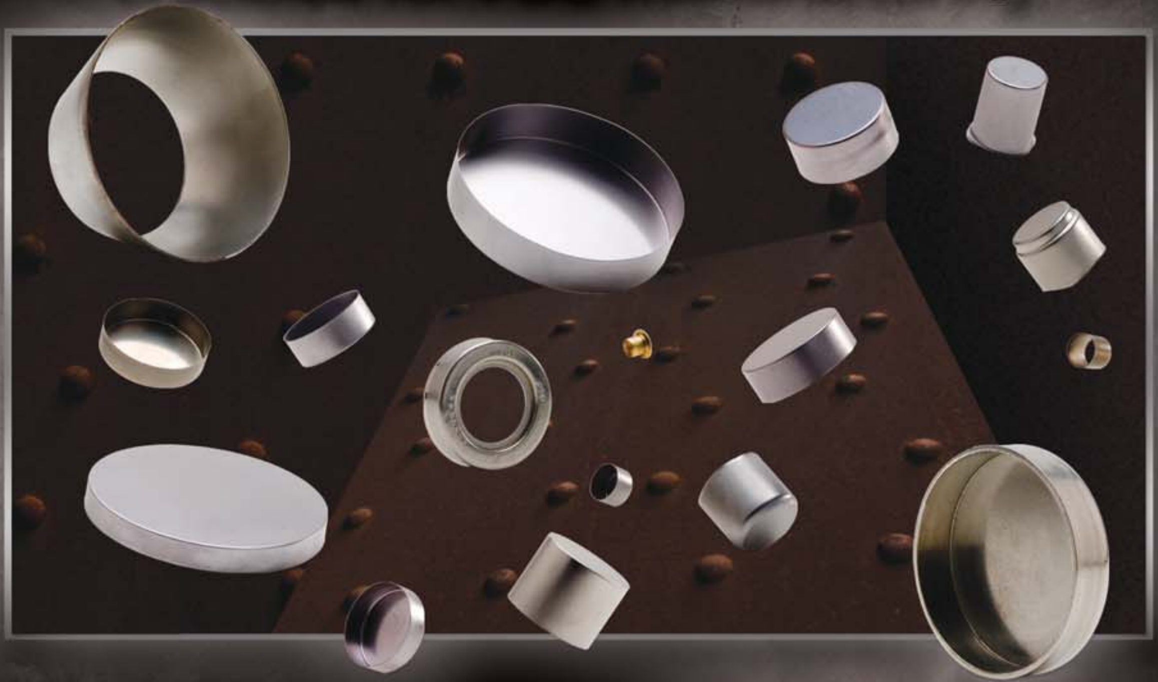

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